YAWL - User Manual

Version 2.2

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Document Control

Arthur ter Hofstede	version 1.9	September 2008	Consolidation of previous documents, conversion to LaTeX of some of them, general cleaning and extensions (e.g. new chapter on engine).
Arthur ter Hofstede	version 1.99	October 2008	First version of chapter on resource perspective.
Michael Adams	version 2.0	July 2009	Major rewrite and additional sections to align the manual with v2.0. Public release version for YAWL 2.0.
Michael Adams	version 2.0f	September 2009	Updates for several minor Editor enhancements and addition of the Twitter Service & iGoogle Gadget.
Michael Adams	version 2.1b	June 2010	Updates for version 2.1.
Marcello La Rosa	version 2.1c	February 2011	Update for C-YAWL.
Michael Adams	version 2.2	August 2011	Revision of entire manual and additions for YAWL 2.2.

Feedback?

Any feedback regarding this manual is very much appreciated. If you find there is a topic that is missing or has not been sufficiently well-explained, please send your feedback to `yawlmanual@gmail.com`. All suggested improvements will be incorporated into future versions of the manual.

Sources

The first version of this document (1.9) combined the following documents:

1. A "New Features" document produced by Lachlan Aldred.

2. A "Getting Started with YAWL" document by Lindsay Bradford and Marlon Dumas. This forms the basis for Chapter 3.

3. A "Editor 2.0 User Manual" document of which first versions were produced by Sean Kneipp and subsequent versions by Lindsay Bradford, Jessica Prestedge, Marcello La Rosa, and Michael Adams. This document was copied into Chapter 4.

4. A "Data Manipulation in YAWL" document by Chun Ouyang (with some of the figures on the use of XML technology in YAWL taken from a presentation by Lachlan Aldred). This forms the basis for Chapter 5.

5. A "YAWL Engine User Manual" (Beta 8 release) document created by Sean Kneipp with subsequent additions/updates by Guy Redding, Lachlan Aldred and Michael Adams. This document provided inspiration for Chapter 6.

6. A "The Worklet Custom Service for YAWL - Installation and User Manual" document created and later revised by Michael Adams. Lachlan Aldred merged the installation manual. This document was copied into Chapter 8.

7. An "Installation Manual" (Engine Beta 8.2 - Editor 1.5) first created by Sean Kneipp and with subsequent changes/corrections/extensions by Guy Redding, Lachlan Aldred, Petia Wohed, Michael Adams, Moe Wynn, and Marcello La Rosa. This forms the basis for Chapter 2. Its introduction forms the basis for Chapter 1.

Chapter 1

Introduction

This chapter provides a brief background introduction to YAWL and the YAWL Foundation.

1.1 What is YAWL?

Based on a rigourous analysis of existing workflow management systems and workflow languages, a new workflow language called YAWL (Yet Another Workflow Language) was developed by Wil van der Aalst (Eindhoven University of Technology, the Netherlands) and Arthur ter Hofstede (Queensland University of Technology, Australia) in 2002. This language was based on the one hand on Petri nets, a well-established concurrency theory with a graphical representation, and on the other hand on the well-known Workflow Patterns (www.workflowpatterns.com). The Workflow Patterns form a generally accepted benchmark for the suitability of a process specification language. Petri nets can capture quite a few of the identified control-flow patterns, but they lack support for the multiple instance patterns, the cancellation patterns and the generalised OR-join. YAWL therefore extends Petri nets with dedicated constructs to deal with these patterns.

YAWL offers the following distinctive features:

- YAWL offers comprehensive support for the control-flow patterns. It is the most powerful process specification language for capturing control-flow dependencies.
- The data perspective in YAWL is captured through the use of XML Schema, XPath and XQuery.
- YAWL offers comprehensive support for the resource patterns. It is the most powerful process specification language for capturing resourcing requirements.
- YAWL has a proper formal foundation. This makes its specifications unambiguous and automated verification becomes possible (YAWL offers two distinct approaches to verification, one based on Reset nets, the other based on transition invariants through the WofYAWL editor plug-in).
- YAWL has been developed independent from any commercial interests. It simply aims to be the most powerful language for process specification.
- For its expressiveness, YAWL offers relatively few constructs (compare this e.g. to BPMN!).
- YAWL offers unique support for exceptional handling, both those that were and those that were not anticipated at design time.
- YAWL offers unique support for dynamic workflow through the Worklets approach. Workflows can thus evolve over time to meet new and changing requirements.
- YAWL aims to be straightforward to deploy. It offers a number of automatic installers and an intuitive graphical design environment.

- Through the BPMN2YAWL component, BPMN models can be mapped to the YAWL environment for execution.
- The Declare component (released through declare.sf.net) provides unique support for specifying workflows in terms of constraints. This approach can be combined with the Worklet approach thus providing very powerful flexibility support.
- YAWL's architecture is Service-oriented and hence one can replace existing components with one's own or extend the environment with newly developed components.
- The YAWL environments supports the automated generation of forms. This is particularly useful for rapid prototyping purposes.
- Tasks in YAWL can be mapped to human participants, Web Services, external applications or to Java classes.
- Through the C-YAWL approach a theory has been developed for the configuration of YAWL models. For more information on process configuration visit www.processconfiguration.com.
- Simulation support is offered through a link with the ProM (www.processmining.org) environment. Through this environment it is also possible to conduct post-execution analysis of YAWL processes (e.g. in order to identify bottlenecks).

1.2 Obtaining the Latest Version of YAWL

As new versions of the YAWL Environment are released to the public, they will be available for download at the YAWL Sourceforge website (sourceforge.net/projects/yawl). From this site it is also possible to access the source code of all components for development purposes.

1.3 The YAWL Foundation

For up-to-the-minute information on any aspect of the YAWL Initiative, visit the YAWL Foundation Homepage (yawlfoundation.org). The YAWL Foundation is a non-profit organisation that acts as custodian of all intellectual property (IP) related to YAWL and its support environment.

1.4 Documentation

Apart from this user manual, there is a technical manual on YAWL and a number of case studies. These studies provide detailed examples that you may wish to consult in order to obtain a deeper understanding of the application of YAWL.

This manual does not really cover the control-flow *concepts* of YAWL in detail. One reason for this is that there are quite a few papers out there that do provide this information. We refer the reader to e.g. [5] for a justification of the extensions of Petri nets introduced for YAWL on the basis of the original control-flow patterns. The main paper on YAWL, from a language point of view, is [6]. In this paper you find a formalisation of the control-flow concepts of YAWL. More recently, a CPN formalisation of newYAWL (control-flow, data and resource perspectives) was presented in [22]. For a formalisation of the OR-join, a complex synchronisation concept in YAWL, we refer to [26]. This definition supersedes the definition provided in [6].

As mentioned above, YAWL extends Petri nets. There are a number of general introductions to Petri nets in the literature. We refer the interested reader to [16, 14].

Wil van der Aalst has written much about the application of Petri nets to workflow, see e.g. [1]. The subclass of Petri nets introduced by him, Workflow-nets, is a predecessor of YAWL. The textbook that he wrote together with Kees van Hee is highly recommended reading [4].

A recent textbook on Business Process Management (BPM), which covers the original control-flow patterns and also YAWL, was written by Mathias Weske [24]. This textbook also covers other approaches, such as the modelling standard BPMN (note that the BPMN2YAWL tool can convert these specifications to YAWL).

On the YAWL web site (`yawlfoundation.org`) it can be seen how the original control-flow patterns can be realised in YAWL (follow the link on Resources and then click 'patterns'). For control-flow patterns in newYAWL the reader can consult appendix A.1 of Nick Russell's PhD thesis [22].

If you would like to know more about how verification of YAWL specifications really works, we refer you to [23] and to [25]. This work forms the theoretical basis of how the verification mechanisms are realised in the YAWL editor.

In-depth discussion of YAWL's exception handling framework from a conceptual point of view can be found in [22, 18] and from an implementation aspect in [7, 8]. YAWL's worklet approach to dealing with on-the-fly changes to workflows is discussed in [7, 9].

The reader that is interested in declarative specification of workflow is referred to [15]. On the Declare web site, `declare.sf.net`, the Declare service for YAWL can be downloaded. Further documentation about this approach can also be found there.

YAWL has a close link to the Process Mining environment ProM [3], `www.processmining.org`. This link is for example exploited in [17] to provide simulation support for YAWL. There exists support for exporting YAWL logs to ProM which can subsequently be analysed by one of the many mining plug-ins available in this environment.

Alternative ways of presenting work lists have been addressed in [10]. In this framework users can choose a map (not just a geographical map, but also e.g. a timeline or a YAWL specification) and work items can be positioned on this map and be shown in a colour that reflects their level of urgency (a context-specific notion which can be defined for the user). It is expected that this work becomes part of the YAWL distribution in the near future.

Finally, a textbook on YAWL, called *Modern Business Process Automation: YAWL and its Support Environment* has been published by Springer (2010; ISBN: 978-3-642-03120-5).

Chapter 2

Installation

The YAWL System (also referred to as the YAWL Environment) comprises a number of web servlets and a java-based Editor desktop application. It requires a *Servlet Container* to host the servlets and a back-end database system for process data storage and archiving. Individual YAWL components may be installed manually (see Section 2.4), but there are also a number of automatic YAWL installation packages that install all the required components and allow you to be up and running with YAWL quickly and easily:

- **YAWL4Study** is available for Windows, Linux and Mac OSX platforms. This is the installer to choose if YAWL is to be used within a single user environment (for example, to write a research paper based on YAWL or to prepare your next workflow lecture). Furthermore, YAWL4Study is the right choice if you intend to learn about or to experiment with YAWL. The resulting pre-configured installation has the complete YAWL functionality and contains the same YAWL components as *YAWL4Enterprise*.

- **YAWL4Enterprise** is an installer for Windows only. Third-party components like Apache Tomcat and PostgreSQL are installed separately as services so that YAWL can be used as a long-running server for production purposes. Furthermore, this installer allows for some configuration of the YAWL environment. For production purposes on a Windows platform this is the installer to choose. See Section 2.4 for instructions on how to install the enterprise version of YAWL for multi-user production environments on other operating platforms.

The complete YAWL environment is installed whichever installer is chosen. Further information on the different installer types can be found on the YAWL project web-page on SourceForge[1].

	Installing	Maintaining	YAWL Engine	YAWL Editor	Purposes
YAWL4Study	Easy	Easy	✔	✔	Fits for all purposes; except long running workflows
YAWL4Enterprise	Tricky	Tricky	✔	✔	Long running workflows
YAWLive	Medium	Easy	✔	✔	Sandbox; minimal persistence possible

Figure 2.1: YAWL product comparison

Official and stable versions of the YAWL installation files are found on the YAWL project web-page on sourceforge[2] under *Download*, release package *YAWL Complete*.

[1] http://sourceforge.net/projects/yawl/files/YAWLComplete/Release2.1beta/yawl2.1beta_version_difference.pdf/download

[2] http://sourceforge.net/projects/yawl/

2.1 Requirements

All installers require the Java SE Runtime Environment (JRE), 1.5 or greater (java.sun.com).

YAWL4Study for Linux requires installed xdg-utils (portland.freedesktop.org), which should be supported by your desktop environment (GNOME and KDE do support xdg-utils), in order to visualise YAWL Editor menu entries.

YAWL 2.2 has been successfully run on the following operating systems:

- **Windows**: XP, Vista, Windows 7, Server;
- **Linux**: Ubuntu (9.10), sidux, Debian (Etch);
- **Mac OSX**: Tiger, Leopard, Snow Leopard.

2.2 Installing YAWL4Study

The release package provides an installer for each of the operating systems Windows, Linux and Mac OSX. Their filenames are similar to those shown in Table 2.1.

	Windows	YAWL4Study-**windows**-2.2-installer.exe
	Linux	YAWL4Study-**linux**-2.2-installer.bin
	MacOSX	YAWL4Study-**osx**-2.2-installer.app.zip

Table 2.1: YAWL4Study is available for three different operating systems

Preparation YAWL4Study can be installed from an ordinary user account without administration rights as long as Java version 1.5 or greater is installed on the system.

To start the installation, simply double-click on the installation file.

The installation file needs to have read and executable permissions. Those can be assigned by right clicking the file, selecting *Properties* and setting the appropriate permissions. Alternatively the following shell command can be applied:

```
user@host:/tmp$ chmod 755 YAWL4Study_linux_2.0_RC1.bin
```

Afterwards, start the installation by double-clicking on the downloaded file or by invoking it from the command line:

```
user@host:/tmp$ ./YAWL4Study_linux_2.0_RC1.bin
```

Installation Start You will first be greeted by a Welcome screen. Pressing *Next* will take you to the License Agreement page, shown in figure 2.2. The license agreement contains the Gnu Lesser General Public License (Version 2.1), the Apache License (Version 2.0), the BSD License and Sun's Binary Code License Agreement. You need to accept the agreements to continue the installation.

The next step is to select the installation directory (figure 2.3). The default location is your home directory. The installer will inform you if you're allowed to install YAWL in the selected folder. In case of Windows or Linux, folders like *C:\Program Files* or */usr/local/* are only writeable by users with administrative rights. Install YAWL into your home directory if you don't have administrative rights.

After clicking *Next*, the installer will look for a valid Java installation. The dialog box in figure 2.4 will only appear if Java has been detected on your system.

License Agreement
Please read the following License Agreement. You must accept the terms of this agreement before continuing with the installation.
GNU LESSER GENERAL PUBLIC LICENSE
Version 2.1, February 1999
Copyright (C) 1991, 1999 Free Software Foundation, Inc.
51 Franklin Street, Fifth Floor, Boston, MA 02110-1301 USA
Everyone is permitted to copy and distribute verbatim copies
of this license document, but changing it is not allowed.
[This is the first released version of the Lesser GPL. It also counts
as the successor of the GNU Library Public License, version 2, hence
Do you accept this license?
I accept the agreement
I do not accept the agreement
BitRock Installer
Back
Forward
Cancel

Figure 2.2: License Agreement

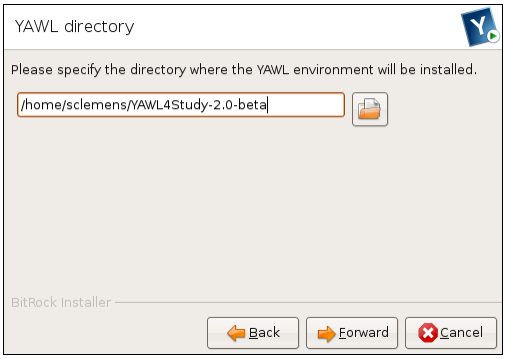


Figure 2.3: Select Installation Directory

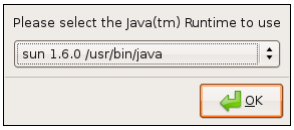


Figure 2.4: Select Java Version

If no Java version greater or equal 1.5 is found and the YAWL4Study for Windows installer is executed, the supplied Java version will be installed.

The installation will stop if no Java version greater or equal 1.5 is found. Install the latest Java version before executing the YAWL installer. The YAWL installer checks the usual installation paths, like */usr/* or */usr/local/*. If you installed Java on your system but the YAWL installer is not able to find it, create the following link:

```
user@host:$ ln -s /path/to/your/java/base/dir /usr/local/java
```

Keep in mind that you need administration rights to generate the link. Afterwards, start the YAWL installation again.

You are now ready to proceed with the installation. When the installation completes, you will see the *Installation Completed* page. If you found a problem and could not complete the installation, please post the problem to the sourceforge forum[3].

Database YAWL4Study comes with a pre-built and preconfigured Apache Derby[4] database.

[3] http://sourceforge.net/forum/forum.php?forum_id=391803
[4] http://db.apache.org/derby/

2.3 YAWL4Enterprise

The release package on the YAWL project web-page on sourceforge[5] provides an installation file for Windows. In contrast to YAWL4Study, YAWL4Enterprise allows the configuration of third-party components like the application servlet container and the database server.

Preparation YAWL4Enterprise should be installed with an administrator account. Installation is started by simply double-clicking on the installation file.

Installation After being greeted by the Welcome screen and pressing *Next*, you'll see the License Agreement page. The license agreement contains the Gnu Lesser General Public License (Version 2.1), the Apache License (Version 2.0), the BSD License and Sun's Binary Code License Agreement. You need to accept the agreements to continue the installation. In the next step you are given the choice to update YAWL (but only if the same YAWL version is already installed), to do a standard installation, or to install YAWL and conduct a comprehensive configuration of its third party components. If you choose to update YAWL, existing configurations are used to update the current YAWL installation.

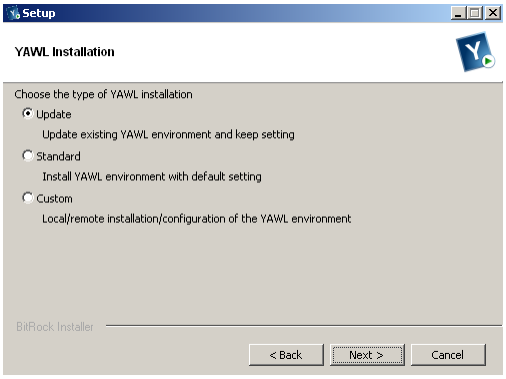


Figure 2.5: Type of YAWL4Enteprise Installation

The next step is to select the installation directory and to choose a Java installation. The dialogue box in figure 2.6 will only appear if Java greater or equal 1.5 is detected on your system.

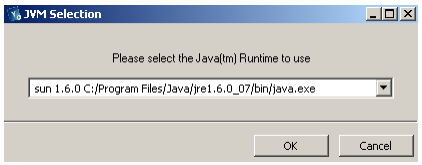


Figure 2.6: Select Java Version

Within the next steps the installation path and port numbers (see figure 2.7) of Apache Tomcat are set. The default port numbers are fine in most cases, and only need to be changed if those ports are already in use.

The YAWL4Enterprise installer gives you the choice of installing a supplied version of PostgreSQL or to use an already installed PostgreSQL or MySQL version (see figure 2.8).

If you choose to install PostgreSQL and the YAWL DB, the PostgreSQL installation directory and different PostgreSQL settings can be specified (see figure 2.9). Again the default settings are suitable in most cases.

The last installation panel allows specifying whether Apache Tomcat and/or PostgreSQL should run as services.

[5] http://sourceforge.net/projects/yawl/

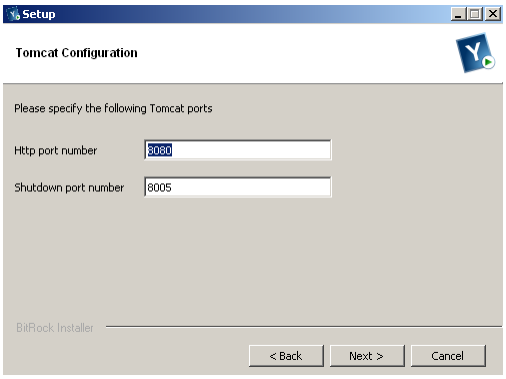


Figure 2.7: Set up of Tomcat Ports

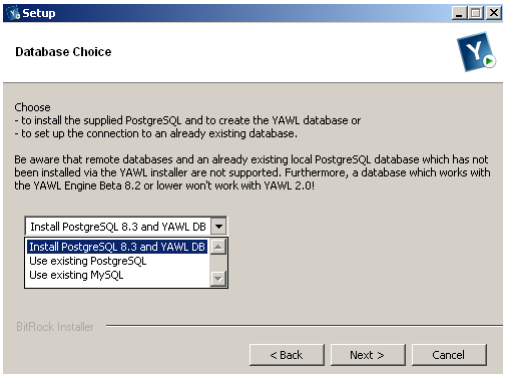

Setup
Database Choice
Choose
- to install the supplied PostgreSQL and to create the YAWL database or
- to set up the connection to an already existing database.
Be aware that remote databases and an already existing local PostgreSQL database which has not been installed via the YAWL installer are not supported. Furthermore, a database which works with the YAWL Engine Beta 8.2 or lower won't work with YAWL 2.0!
Install PostgreSQL 8.3 and YAWL DB
Install PostgreSQL 8.3 and YAWL DB
Use existing PostgreSQL
Use existing MySQL
BitRock Installer
< Back
Next >
Cancel

Figure 2.8: Specification of Database

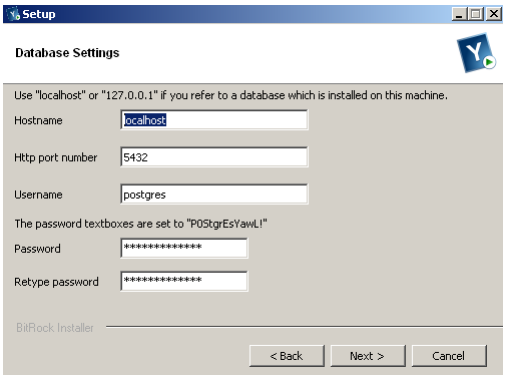


Figure 2.9: Specification of PostgreSQL settings

2.4 Manual Installation

If you already have Apache Tomcat (version 5.5.26 or greater) and/or PostgreSQL (version 8.1 or greater) and/or a previous version of YAWL, you may prefer to install specific components only. Alternately, you may wish to use a different database back-end than PostgreSQL, or a different servlet container than Apache Tomcat. Manual installation is also required if you want a multi-user, production-level installation on an OS platform other than Windows. This section details how to install YAWL 2.2 on a component-by-component basis.

2.4.1 Installing Tomcat

YAWL mainly consists of a number of servlets, and so needs a servlet container installed to host them. We recommend Apache Tomcat be used – it is free, stable and fully tested as a YAWL host over a number of years. YAWL requires Tomcat version 5.5.26 or later.

The first step is to download the latest Tomcat version from tomcat.apache.org. The simplest way to install Tomcat in a Windows environment is to use the purpose built Windows installer provided.

For installation on Mac OSX, follow the instructions at wiki.apache.org/tomcat/TomcatOnMacOS. Ignore the first half of the page; start from the heading 'Updated for 2006'. The steps for starting the firewall and enabling port-forwarding are not required from a YAWL perspective.

Linux installation is quite straightforward. A simple set of instructions (for ubuntu) can be found at www.howtogeek.com/howto/linux/installing-tomcat-6-on-ubuntu/

In all cases, an environment variable called "CATALINA_HOME" needs to be added, which points to the tomcat install path.

Once Tomcat is installed, two small configuration changes are required to files found in the *<your_tomcat_dir>/conf* directory:

1. **context.xml**: Locate the commented line containing *<Manager pathname="" />* and uncomment it.
2. **server.xml**: Locate the entry that begins *<Connector port="8080" protocol="HTTP/1.1"* and modify it so that it looks like this (i.e. the fifth attribute, *URIEncoding="UTF-8"*, has been added):

```
<Connector port="8080"
   protocol="HTTP/1.1"
   connectionTimeout="20000"
   redirectPort="8443"
   URIEncoding="UTF-8"/>
```

2.4.2 Installing PostgreSQL

As a default, YAWL is configured to use PostgreSQL for database support, and this section describes how to manually install and configure PostgreSQL for YAWL (however, it is easy to configure YAWL for other database back-ends – see Section 2.4.4 for details).

Download the latest version of PostgreSQL from www.postgresql.org/download/ – there is a one-click installer available for each operating system. The following is a walkthrough for a Windows installation, but it is a similar process for other platforms. Except where otherwise mentioned, simply accept the default setting for each setup screen.

For the *Service Configuration* screen, choose the *Install as a Service* option (see Figure 2.10). Leave the account name as 'postgres' and enter any password of at least 6 characters. This will be the account the PostgreSQL service uses to run and allow connections to the database. **Note:** The *Install as a Service* option is only available on Windows systems. On other platforms.

On the next screen, *Initialise Database Cluster* (Figure 2.11), leave all values as they are, but enter 'yawl' (no quotes, all lower case) as the password. This is the user account that YAWL uses to connect to the database (but see Section 2.4.4 for details on how to modify the password YAWL uses). Leave the settings for all other screens at their defaults and click through to completion.

Next, run the administration tool *pgAdmin*[6], which was installed along with the PostgreSQL installation. In the *Object Browser* panel on the left (cf. Figure 2.12), double-click on the *Postgres* server, and, when prompted, enter 'yawl' as the password (you should only be asked for this password the first time you connect). Then, right-click on *Databases* (under Postgres) and choose *New Database* from the popup menu. In the next dialog, enter 'yawl' as the database name, leave all other fields as they are, and click OK.

[6] www.pgadmin.org

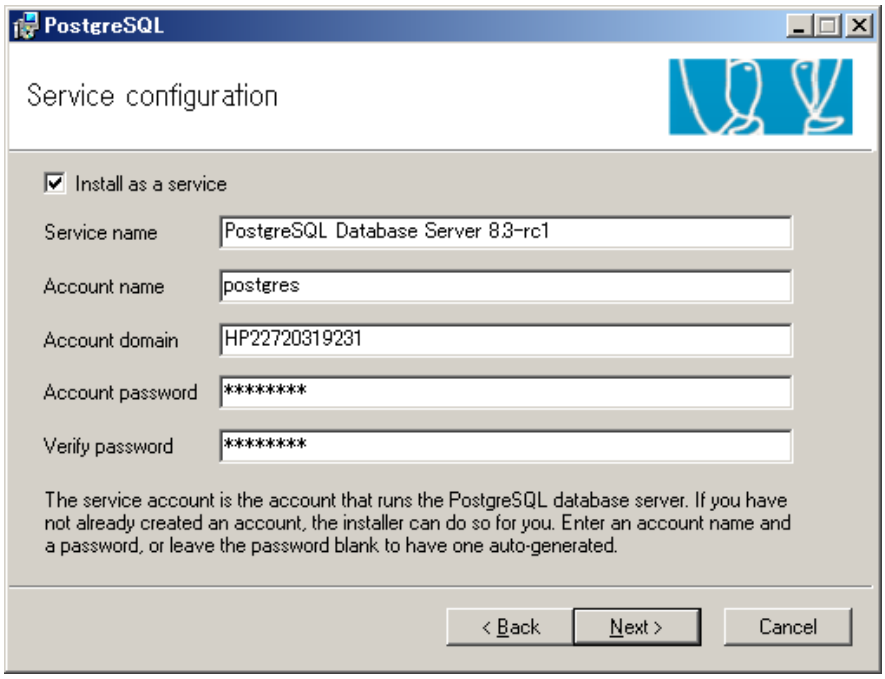

PostgreSQL
Service configuration
Install as a service
Service name
PostgreSQL Database Server 8.3-rc1
Account name
postgres
Account domain
HP22720319231
Account password
****
Verify password
****
The service account is the account that runs the PostgreSQL database server. If you have not already created an account, the installer can do so for you. Enter an account name and a password, or leave the password blank to have one auto-generated.
< Back
Next >
Cancel

Figure 2.10: Choose *Install as a Service* and enter any password

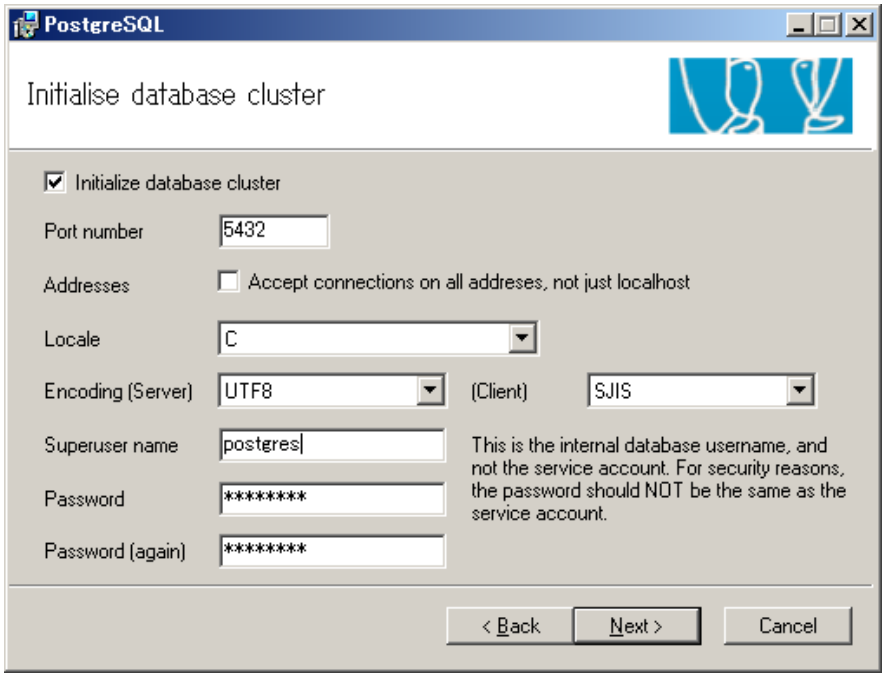


Figure 2.11: Keep *postgres* as the Superuser name, and enter *yawl* as the password

That completes the installation of PostgreSQL and the admin tool pgAdmin, and the creation of the YAWL database. When YAWL is started, it will automatically create the required database tables as part of its startup process.

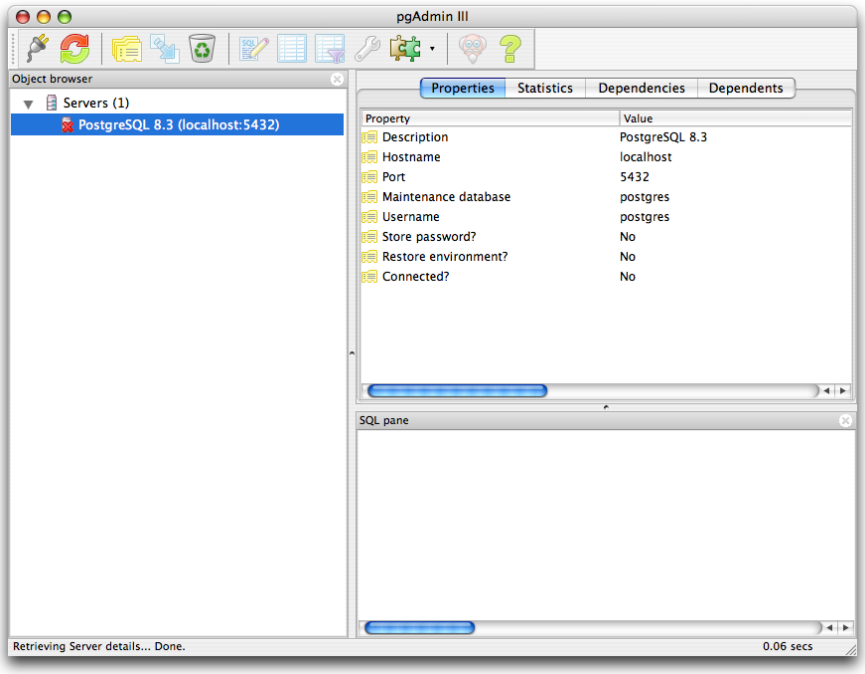


Figure 2.12: The pgAdmin tool, Object Browser panel on the left

2.4.3 Installing YAWL Services

All the necessary YAWL files can be downloaded from the YAWL Engine download page on SourceForge (http://sourceforge.net/projects/yawl/files/YAWL%20Engine/). The latest release folder will contain these files:

- **YAWL_2.2_CoreWebServices.zip**: The core set of YAWL services, comprising the core Engine, and the Resource, Worklet, Web Service Invoker, SMS Invoker, Mail and Monitor Services.
- **YAWL_2.2_OptionalWebServices.zip**: Extra services that you may find useful.
- **YAWL_2.2_LibraryJars.zip**: Two library jars that contain the YAWL class files only (i.e. without any third party libraries) and so can be used to embed references to the YAWL classes when developing applications. The file *yawl-lib-2.2.jar* contains every Engine and Service class file in the YAWL environment, while the file *YResourceServiceClient.jar* contains the minimum set of YAWL classes required when developing applications using the Resource Service's APIs, or when developing custom forms for your processes (see Chapter 4, Section 4.13).
- **YAWL_Standalone_2.2.jar** A basic, standalone desktop version of the Engine.
- **YAWL_SourceAndTestCode_2.2.zip** The source code for the environment.

Download the *CoreWebServices* file (and, if any of the optional services are required, the *OptionalWebServices* file). Unzip the contents of the file to *<your_tomcat_dir> /webapps* directory. When Tomcat is (re)started, it will automatically unpack each war file into its own directory under *webapps* (cf. Figure 2.13). There are six core web services:

1. **yawl.war**: the core workflow engine.
2. **resourceService.war**: handles the allocation of tasks to resources; contains the default worklist handler; generates dynamic forms; manages codelets; manages organisational data.

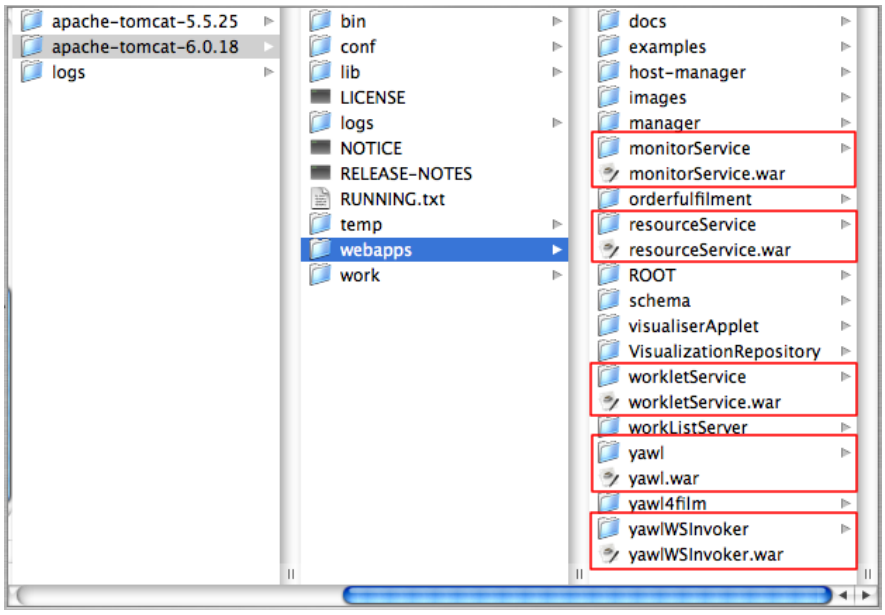


Figure 2.13: YAWL Core Services deployed in /webapps directory (OSX Example)

3. **workletService.war**: handles dynamic flexibility and exception handling.

4. **yawlWSInvoker.war**: allocates tasks to synchronous web services.

5. **yawlSMSInvoker.war**: allows tasks to be read and modified via SMS Services.

6. **mailService.war**: sends emails base on task data to specified recipients.

7. **monitorService.war**: provides basic monitoring capabilities for active processes.

The Resource Service is described in detail in Chapter 6. The Worklet Service is described in detail in Chapter 8. The WS Invoker, SMS and Mail Services are described in Chapter 9. The Monitor Service is described in Chapter 7.

There are three optional web services:

1. **digitalSignature.war**: authenticates the information provided on a form using a digital signature via X.509 certificates and private keys.

2. **mailSender.war**: (*Deprecated*) provides a custom form for a task, from which an email can be sent.

3. **twitterService.war**: allows status updates to be sent from processes directly to a twitter account.

While all the core web services are pre-registered in the Engine when it first starts, the optional services are not, and so require manual registration after installation before they can be used. Please see Chapter 6, Section 6.4.3 for more details.

Tip: If a .war file is to be copied into the *webapps* directory to replace a file of the same name, it is advisable to first shutdown Tomcat, and delete the unpacked directory for that war, before copying in the new war file. On restart, the new war's contents will be unpacked. If the old unpacked directory is not removed, on restart the new war file *will not* unpack. If Tomcat is running when the new war is copied to the *webapps* directory, it *will* unpack and replace the old directory, but, depending on how it has been configured, may run out of resources while doing so, resulting in an *OutOfMemoryError*.

2.4.4 Configuring YAWL for other Databases

YAWL uses Hibernate (hibernate.org) as a database framework, which provides a transparency layer between YAWL and the back-end database used to support it. While the Enterprise version of YAWL is pre-configured to use PostgreSQL, it is a relatively simple process to reconfigure for other databases. Besides PostgreSQL, YAWL has been successfully tested with MySQL, HypersonicSQL, Oracle and Apache Derby (used by YAWL4Study), and other database platforms are known to work well with Hibernate (see www.hibernate.org/80.html for the complete list) and so should have no trouble working with YAWL too[7].

Each YAWL service that communicates with the database (i.e. the Engine, Resource Service and Worklet Service) has a configuration file called *hibernate.properties* located in its *WEB-INF/classes* directory. The properties file contains a 'Platforms' section with default settings for a number of different database platforms – all except one (PostgreSQL) commented out (see Listing 2.1 for an excerpt of the properties file). To configure for a different database platform, comment out the currently enabled platform, then uncomment the platform of choice, ensuring the username and password values match the target database authorisations.

Remember to change the *hibernate.properties* file for each of the webapps mentioned above.

2.4.5 Troubleshooting Memory Problems

By default, Tomcat is configured to use the default memory parameters of the installed Java Virtual Machine (JVM). While this is sufficient for individual users, or even small groups, when larger numbers of users access YAWL concurrently, you may experience an *OutOfMemoryException* and Tomcat will freeze. If you do experience this problem, the solution is to configure Tomcat to have a larger amount of memory allocated to it when it starts.

The default memory allocation is 64 megabytes. Depending on the RAM you have available, a setting of between 256 and 512 megabytes is usually sufficient in the majority of cases.

To set the Tomcat memory allocation in a Windows environment:

1. In a text editor, create a new file and enter the line: `set JAVA_OPTS=-server -Xmx256m`
2. Save the file as */your_tomcat_dir*/bin/**setenv.bat**

To set the Tomcat memory allocation in a *nix or OSX environment:

1. In a text editor, create a new file and enter the line: `export JAVA_OPTS="-server -Xmx256m"`
2. Save the file as */your_tomcat_dir*/bin/**setenv.sh**

These instructions use 256m as an example; please replace it as necessary with the actual amount of memory you'd like to have allocated to Tomcat when it starts.

[7] Please pass on your experiences using YAWL with database platforms, other than those listed, on the YAWL forum.

```
## HypersonicSQL

#hibernate.dialect org.hibernate.dialect.HSQLDialect
#hibernate.connection.driver_class org.hsqldb.jdbcDriver
#hibernate.connection.username sa
#hibernate.connection.password
#hibernate.connection.url jdbc:hsqldb:file:./webapps/yawl/yawl


## PostgreSQL

hibernate.dialect org.hibernate.dialect.PostgreSQLDialect
hibernate.connection.driver_class org.postgresql.Driver
hibernate.connection.url jdbc:postgresql:yawl
hibernate.connection.username postgres
hibernate.connection.password yawl
#hibernate.query.substitutions yes 'Y', no 'N'


## DB2

#hibernate.dialect org.hibernate.dialect.DB2Dialect
#hibernate.connection.driver_class COM.ibm.db2.jdbc.app.DB2Driver
#hibernate.connection.url jdbc:db2:test
#hibernate.connection.username db2
#hibernate.connection.password db2

...

## MySQL

##hibernate.connection.driver_class org.gjt.mm.mysql.Driver
#hibernate.dialect org.hibernate.dialect.MySQLDialect
#hibernate.connection.driver_class com.mysql.jdbc.Driver
#hibernate.connection.url jdbc:mysql:///yawl
#hibernate.connection.username root
#hibernate.connection.password


## Oracle

#hibernate.dialect org.hibernate.dialect.Oracle9Dialect
#hibernate.dialect org.hibernate.dialect.OracleDialect
#hibernate.connection.driver_class oracle.jdbc.driver.OracleDriver
#hibernate.connection.username ora
#hibernate.connection.password ora
#hibernate.connection.url jdbc:oracle:thin:@localhost:1521:test
```

Listing 2.1: hibernate.properties file (excerpt) with PostgreSQL settings enabled

Chapter 3

Getting Started with YAWL

3.1 Introduction

Nowadays, organisations are challenged to continuously improve their efficiency and to respond quickly to changes in their environment, such as new business opportunities, competition threats, and evolving customer expectations. It is not surprising then that organisations are paying more attention to capturing, analysing and improving their work practices in a systematic manner. The methods, techniques and tools to do this are collectively known as Business Process Management (BPM).

For IT departments, BPM provides an opportunity to align IT systems with business requirements, and to re-organise existing application infrastructure to better support the day-to-day operations of the organisation. BPM initiatives often translate into requirements for IT systems. Here is where workflow technology comes into play. Business process models produced by business experts are taken as a starting point by software architects to produce a blueprint for a software application that co-ordinates, monitors and controls some or all of the tasks that make up these business processes. Such software applications are called *workflows*. An example of a business process is an order-to-cash process: one that goes from the moment a purchase order for a product or service is received by an organisation to the moment the customer pays for the products, including aspects such as invoicing and shipment. After capturing this process from beginning to end, an organisation may choose to add further details about the people, legacy applications, messages and documents involved, and to deploy a workflow application to co-ordinate this process.

You can build a workflow application using general-purpose software programming platforms, e.g. as a bunch of Web applications, Enterprise Java Beans and legacy applications connected together... but this defeats the purpose of aligning the models produced by business people with the resulting IT systems. This is why one should consider an alternative approach: to develop workflow applications on top of a dedicated *workflow management system*.[1]

Many years ago, workflow was a bit of a dark art, practised by deep-pocketed companies that were able to afford expensive workflow management systems and highly specialised consultants. Today, workflow technology is widely available and its benefits and pitfalls are more widely understood. A word of warning though: while workflow doesn't have to belong to arcane masters of lore, it's also not something to trivialise. If a workflow application is not aligned with the business it's been deployed in, it can be worse than a manual, paper-based bureaucracy. It is therefore important that both business and IT stakeholders follow a sound BPM methodology before attempting to deploy a workflow application.

But assuming you've decided on a workflow solution, it's time to make a choice. You can still choose to pay for a workflow system, or you can get one for free. If you're for the latter, maybe YAWL is for you. YAWL, which stands for *Yet Another Workflow Language*, is a fully open-sourced workflow system (or

[1]The term business process management system (BPMS) is often used to refer to something similar to a workflow management system. The difference is that a BPMS supposedly offers richer functionality for analysing business processes, while workflow systems traditionally focused on the co-ordination of tasks. However, the gap between these two is narrowing, and it is difficult to differentiate modern workflow management systems and BPMSs.

"business process management system" if you prefer). Its tongue-in-cheek name belies the fact that YAWL is rather unique. It's based on a very rich workflow definition language, capable of capturing all sorts of flow dependencies between tasks. It has open interfaces based on Web standards, which enable developers to plug-in existing applications and to extend and customise the system in many ways. It also provides a graphical editor with built-in verification functionality, which helps solution architects and developers to capture workflow models and to automatically detect subtle but potentially nasty errors early-on in the piece. Finally, YAWL is arguably the most mature open-source workflow management system around. From its beginnings as an academic prototype, YAWL has evolved into an enterprise-grade workflow engine thanks to contributions from the YAWL Foundation members, and from the organisations and individuals who have used it. This demonstrated commitment from its users and community of developers also ensures the continuity of the system.

If you think YAWL might be for you, you may be wondering how to learn more. This chapter provides a gentle introduction to the YAWL workflow system. The aim of the chapter is to help people to get YAWL up and running with a minimum of fuss. The chapter doesn't cover all possible features and components of YAWL. Instead, it focuses on some essential aspects that will help you to become familiar enough with YAWL that you feel comfortable designing and executing at least simple workflows. For more information, you may refer to other chapters in this manual, the technical manual or the various academic papers and case studies available at the YAWL web site.[2].

3.2 Terminology

Before jumping in and getting our hands dirty with a real workflow example, let's briefly agree on some basic terms.

Business Process: A set of interdependent activities that need to be performed in response to a business event, to achieve a business objective. Typical examples of business processes are "complaint handling", "order-to-cash", or "credit card approval".

Workflow Application: A software application that co-ordinates the tasks, data and resources that compose a business process, in whole or part. Sometimes the term "workflow" is used as a shorthand for "workflow application".

Workflow Specification: (Also known as *Workflow Model*) A description of a business process to the level of detail required for its deployment into a workflow engine. A workflow specification defines which tasks should be performed, under which conditions and in which order, which data, documents and resources are required in performing each task, etc.

Workflow System: A system that can be used to develop and to run a workflow application. A workflow system usually includes a *process editor* to support the design of workflow models, a *workflow engine* to support the execution of workflow models, and at least one *worklist handler*.

Workflow Engine: The runtime component of a workflow system responsible for determining which tasks need to be performed and when, for maintaining execution logs, and for delegating the performance of tasks to software applications/services or to a worklist handler.

Case: (Also known as *Workflow Instance*) A specific instantiation of a workflow model as a result of an event. For example, an order management workflow is instantiated every time a new order arrives. Each of these orders leads to a different *case*.

Task: (Also known as *Activity*) A description of a unit of work that may need to be performed as part of a workflow. Workflow models are composed of tasks. Generally, a task may be either manually carried out by a person or automatically by a software application.

[2] http://yawlfoundation.org

Work item: (Also known as *Task Instance*) A particular instance of a task that needs to be performed as part of a given workflow instance.

Worklist: A list of work items.

Worklist Handler: (Also known as a *Task Management Service*) A software component that manages work items issued by a workflow engine and that assigns, prioritises and presents these work items to human participants according to policies that may be configured in the workflow model and/or at runtime.

3.3 Building a Simple Workflow Example

Designing a workflow typically begins with a process modelling exercise. A *process modelling expert* sits down with a *domain expert*, and picks their brains on "how things are done". The knowledge gained on the sequencing and nature of the work done is then transformed into an executable workflow. Let's take a look at an example transcript between a process modelling expert, Processa Maree Experta, and her cousin, Domainic Experta, who runs the credit application department of a company called Loans-R-Us.

Processa: *So, how does a credit application begin?*

Domainic: *Well, an application arrives in our office. Once we receive it, we validate the claim.*

Processa: *What happens then?*

Domainic: *We determine what credit requirements there are for the application, then we seek a credit report for the applicant.*

Processa: *So the credit report is requested after the credit requirements are determined?*

Domainic: *Mostly. Sometimes we request the credit report first. Actually, the order in which we do them doesn't really matter.*

Processa: *Ah, so both tasks could be done at the same time?*

Domainic: *Yes, I guess they could.*

Processa: *Then what happens?*

Domainic: *Once we have both the credit report and credit requirements, we can tell whether we need to do a large credit approval, or a small approval. Only senior staff here are allowed to approve large credit applications.*

Processa: *So, what makes a credit application large?*

Domainic: *If the application is for $\$5,000$ or more, it's considered large. Any lesser amount is considered a small application, and can be done by anybody in our department.*

Processa takes this transcript, dumps it on your desk and tells you to implement a workflow to match. What's more, she wants you to do it with YAWL[3].

In a nutshell, a workflow specification in YAWL describes what work needs to be done, when and by whom. Each YAWL specification is composed of one or more YAWL nets: exactly one *starting* net (also known as the root or parent or top-level net) and zero or more sub-nets. In this tutorial, we'll keep things simple and we will only consider the case of a YAWL specification composed of one net (the starting net). A net has two mandatory elements: an input condition which acts as the starting point (graphically represented like this: ▶) and an output condition which signals the end (the ■ symbol). Figure 3.1 depicts the YAWL Editor

[3]This chapter is more an overview of YAWL than an examination of its tool support. The assumed knowledge at this point is that you have installed and can begin using the YAWL toolset by following the instructions provided in Chapter 2.

with a brand new specification open and with the specification's starting net visible. Don't worry too much at this stage about the various components of the Editor – it is described in detail in Chapter 4.

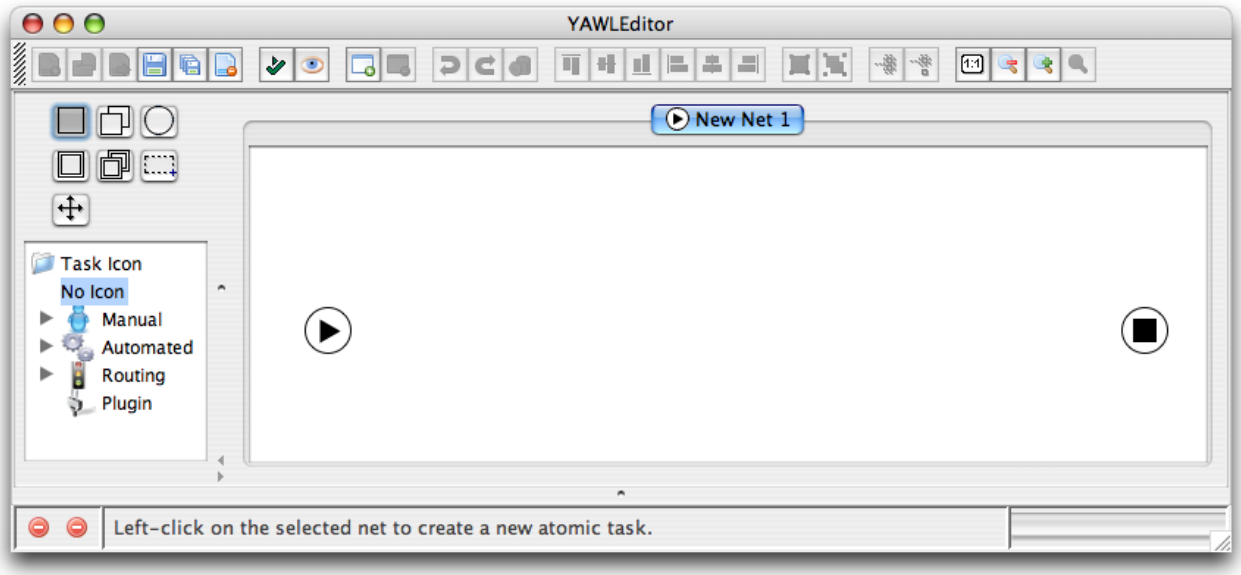


Figure 3.1: A New Specification and its Starting Net

It's time to start modelling the work to be done. Typical workflow specifications in YAWL will make significant use of atomic tasks. An atomic task (represented in YAWL as a square) models a stand-alone piece of work that is either manual or automatic, and it's here that workflow designers starts earning their money. Just how much work should a single atomic task represent? The answer is not always obvious.

Looking again at Processa's transcript, we decide that an initial atomic task is needed for receipting and validating a claim. After that, two additional pieces of work need to be done, but in no particular order. We'll add an atomic task each for determining credit requirements, and seeking a credit report. The next step requires that both credit requirements are determined, and that a credit report be ready. We need an extra task to run only once they are finished which will decide, based on the application amount, whether we then send the application on for a large or a small approval process. We expect large approvals and small approvals to have differing work requirements, so we'll model each type of approval as a separate task.

In all, we've identified six distinct pieces of work. Place six atomic tasks onto the starting net and give each a meaningful label. You should have the skeleton of a workflow that looks something like figure 3.2.

We're now ready to begin describing how the tasks in our starting net are to be ordered in their execution (known as its *control-flow*). The transfer of work between two tasks is done through a "flow". Flows are depicted within YAWL as unidirectional arrows. For a YAWL specification to be valid, every task must be tied into a net via flows that can be traced back to the net's input condition, and which will eventually lead to the net's output condition.

We'll need a flow from the input condition to the *Receive and Validate Application* task, then two flows from that task to the tasks *Determine Credit Requirements* and *Obtain Credit Report* respectively. From each of these, a flow must go to the task *Choose Approval Process*. From this task, we need a flow going to the tasks *Large Credit Approval* and *Small Credit Approval* respectively. From these last two tasks, we need flows to the final output condition.

By default a YAWL task can only have one incoming flow and one outgoing flow. When we need more incoming flows to a task, we must unambiguously state how the task should handle its inflows: should it wait for all of them? Should it wait for only one of them? Or something in the middle? This disambiguation is done by 'decorating' the task with a *join*. A similar situation holds when a task has multiple outgoing flows. In this case, we need to decorate the task with a *split*.

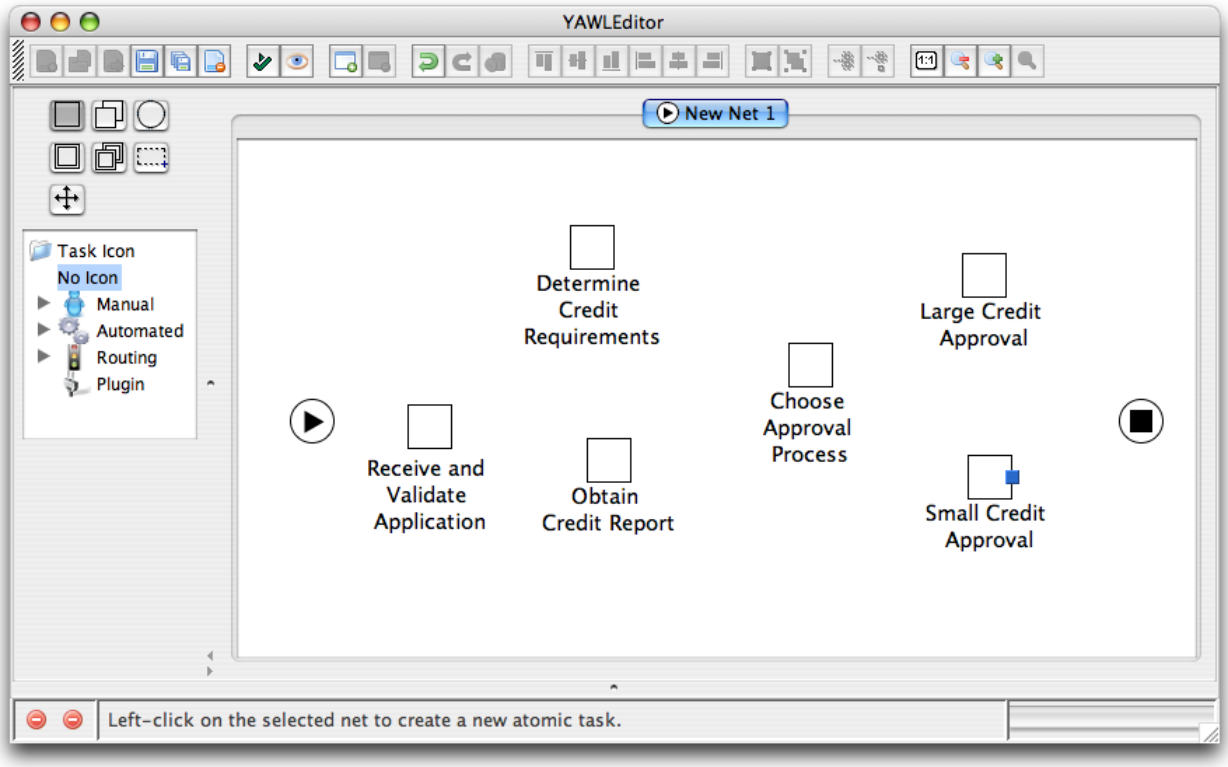


Figure 3.2: Atomic Tasks Added to the Starting Net

Figure 3.3 lists the available joins and splits that can be used on tasks, along with a brief description of the behaviour to expect from tasks when using them.

Returning to our example, the tasks *Receive and Validate Application* and *Choose Approval Process* both require decoration. The first of these two tasks requires an AND-Split because the subsequent tasks can be done in parallel. The second task should have an XOR-split decorator to signal that either of the subsequent tasks should be performed, but not both. With these splits and joins in place, we can now connect the remaining tasks as depicted in figure 3.4.

We now need to say how information passes from YAWL to its participants (e.g. workers and external applications) and how information comes back into YAWL once they're finished. This is done by attaching a *decomposition* to each task. Every atomic task that requires work to be performed needs to have a decomposition. A decomposition may be described as a contract between the task and its 'environment', describing the data that will be assigned and updated when the task is performed and the so-called *YAWL Custom Service* (a web service designed for the YAWL environment) that will be responsible for the task's execution. Note that the YAWL Engine does not directly perform the work of the task – responsibility is always deferred to the designated YAWL Service. It is possible to define an atomic task without assigning it a decomposition: they represent so-called "empty" steps and are generally used to capture a point in the specification where there is a need to synchronise certain tasks and start a new set of tasks.

In our working example, all tasks except one require a decomposition. It is enough at this stage to simply create a decomposition per task. To do this, you need to right-click on each task and select the "Set Task Decomposition" option. For this example, we'll choose the *Default Engine Work-list* (actually the worklist handler built in to the Resource Service) as the "type of decomposition". This tells YAWL that when the task is ready to be executed, it should be displayed in the default worklist. Every instance of the task will then appear in the worklist of human participants so they may receive data relative to the task instance, work on that data, and finally return work results to YAWL. Another type of decomposition, which we won't illustrate in this tutorial, is to associate tasks to a Web Service that can, for example, send notifications to

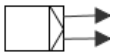
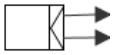
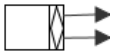
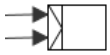
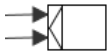
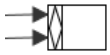
Name:	Symbol:	Description:
Split Types:		
XOR-Split		The XOR-Split is used to trigger *only one* outgoing flow. It is best used for automatically choosing between a number of possible exclusive alternatives once a task completes.
AND-Split		The AND-Split is used to start a number of task instances simultaneously. It can be viewed as a specialisation of the OR-Split, where work will be triggered to start on *all* outgoing flows.
OR-Split		The OR-Split is used to trigger some, but *not necessarily all* outgoing flows to other tasks. It is best used when we won't know until run-time exactly what concurrent resultant work can lead from the completion of a task.
Join Types:		
AND-Join		A task with an AND-Join will wait to receive completed work from all of its incoming flows before beginning. It is typically used to synchronise pre-requisite activities that must be completed before some new piece of work may begin.
XOR-Join		Once *any* work has completed on an incoming flow, a task with an XOR-Join will be capable of beginning work. It is typically used to allow new work to start so long as one of several different pieces of earlier work have been completed.
OR-Join		The OR-Join ensures that a task waits until all incoming flows have either finished, or will never finish. OR-Joins are "smart": they will only wait for something if it is necessary to wait. However, understanding models with OR-joins can be tricky and therefore OR-joins should be used sparingly.

Figure 3.3: Supported Splits and Joins in YAWL

people via SMS and receive replies from them also via SMS.

The one task in our example that does not need a decomposition is the one labelled *Choose Approval Process*. This task does not need any participant interaction because the decision on whether to choose either *Large Credit Approval* or *Small Credit Approval* can be automatically determined with data made available to the workflow instance.

Congratulations, you now have an executable YAWL workflow specification. However, more effort is needed with respect to data and resourcing to achieve real utility. All YAWL can currently do with this specification is walk an unspecified user through a default path of the workflow.

3.4 Advanced Workflow Concepts

A specification capable of only walking a user through a path of a workflow is hardly going to win us any awards in workflow automation. We still have at least two major concerns to address before our specification becomes useful.

Firstly, we need to decide which participants should perform which tasks. This is discussed in section 3.4.1. Secondly, we need to figure out what data these participants need from the workflow system, what data they need to supply the workflow system, and how the workflow system will use data to implement automated choice between alternatives. Concerns involving workflow data are covered in section 3.4.2.

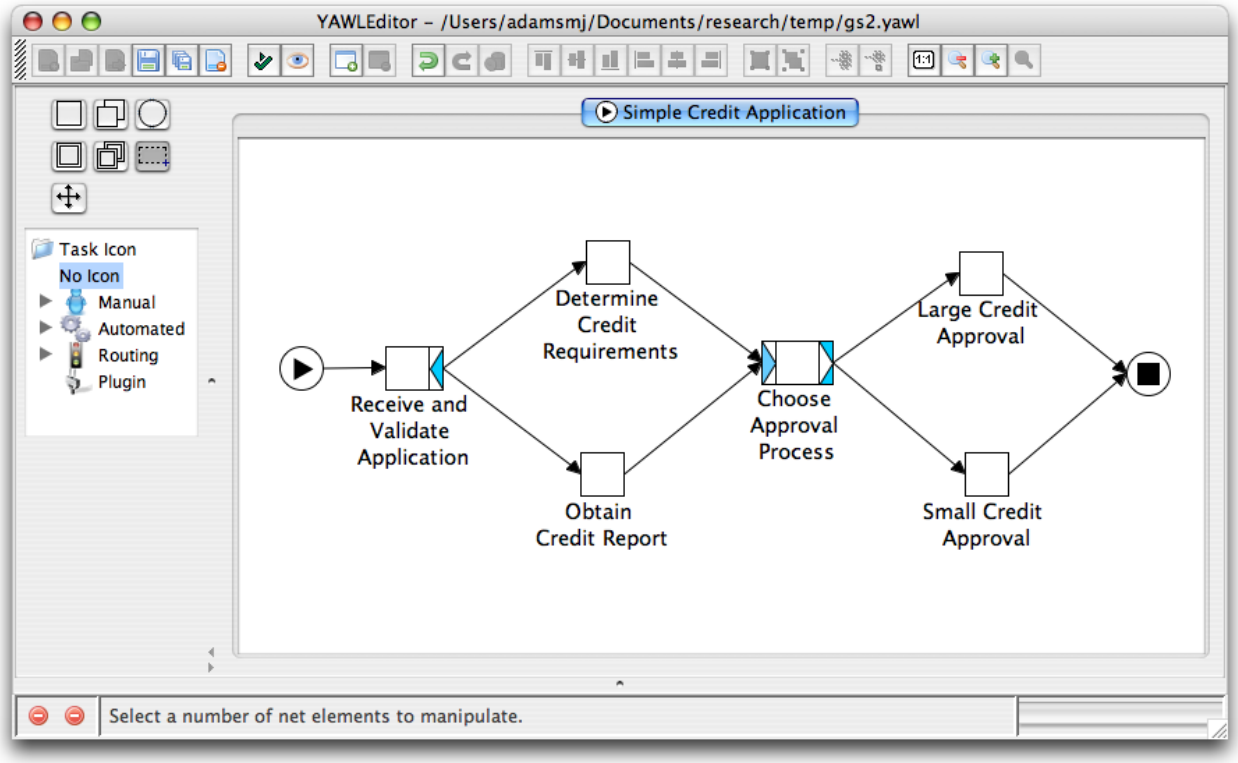


Figure 3.4: Multiple Flows Between Tasks

3.4.1 Modelling Resourcing Requirements

It's time now to add detail to our YAWL specification, describing which participants should be doing particular pieces of the work specified. We'll assume that the entire workflow is to be carried out by the "Applications Department" of Loans-R-Us. All employees within this department are capable of performing the role *Credit Officer*, but a subset of these with several years of experience also perform the role *Senior Credit Officer*. Anyone with the *Credit Officer* role is allowed to approve small credit applications. Only those performing the role *Senior Credit Officer* are allowed to do the final approval of large credit applications.

We therefore have a modelling requirement where every credit officer is capable of processing a credit application right through from its receipt to approval, so long as the application is for a small amount. When it comes to the step of approval for large credit applications, however, only senior staff are allowed to do this approval.

We first need to establish an *organisation model* within a running YAWL system where we identify those participants from the Applications Department. For each of these, we assign the *Credit Officer* role. For the subset of participants recognised as senior, we also assign an extra role of *Senior Credit Officer*.

To define this organisational model you need to log into the YAWL Resource Service (for now, we'll use the generic username *admin* and password *YAWL*). Assuming you used one of the automatic installers, this is simply a matter of starting the engine (choose "Start Engine" from the options shown for the YAWL program) followed by access the Resource Service in a Web Browser (choose "YAWL Control Centre" from the options shown for the YAWL program). When you have logged in you can create new roles by choosing the "Org Data Mgt" form from the menubar, and new participants by choosing the "User Mgt" form from the menubar. This is illustrated in Figure 3.5 where the role "Senior Credit Officer" is defined and Figure 3.6 where the participant "Michael Corleone" is defined and assigned that role.

Once we have defined all the required roles and participants, we can specify resourcing requirements for tasks. Back in the Editor, right click with your mouse on a task and choose "Manage Resourcing" from the

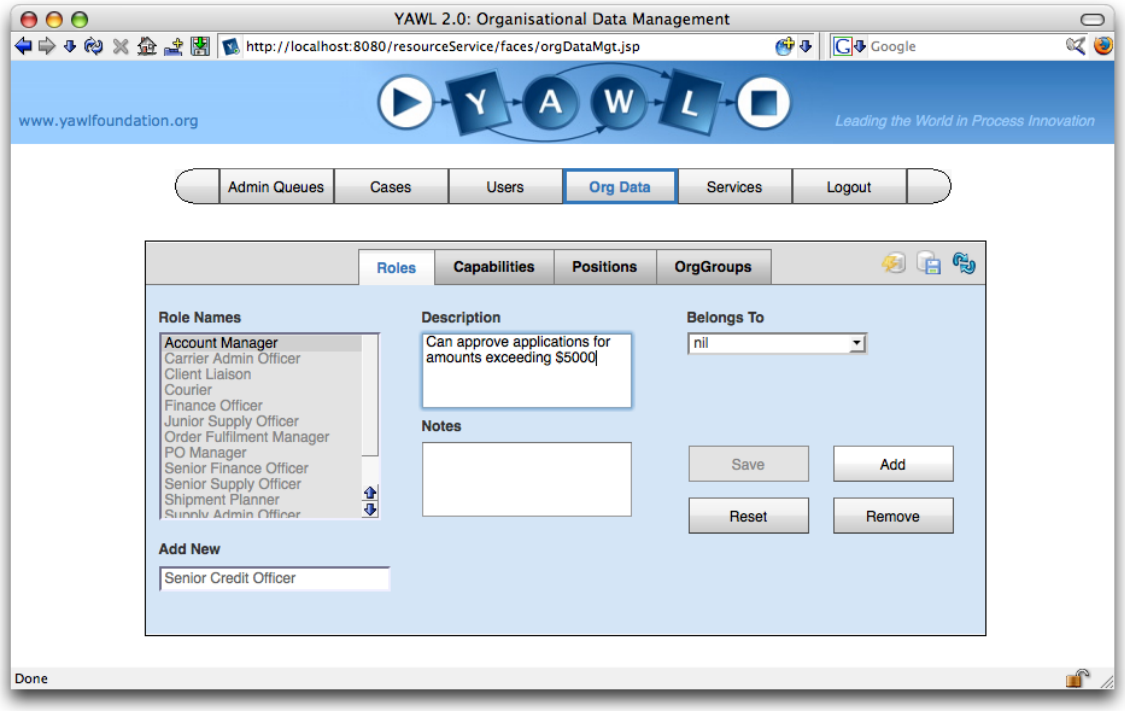


Figure 3.5: Defining a Role

popup menu (this menu item will be disabled for tasks without decompositions defined). The Resourcing Wizard will begin and you can choose the interaction strategy for that task. In Figure 3.7 an interaction strategy is chosen where, at runtime, the system offers a work item to all authorised participants, from where one of these participants can then choose to perform this work item and later choose to actually start working on it. This strategy (Offer: System, Allocation: User, Start: User) is a common interaction strategy for tasks to be executed by participants.

Step 2 of the Resourcing Wizard then allows you to choose who is authorised to execute work items of the particular task. In Figure 3.8 the "Senior Credit Officer" role is assigned to the task, thus guaranteeing that at runtime work items of this task are offered only to participants that perform that role.

Resourcing requirements can be quite complex, and the YAWL environment offers comprehensive support for the vast majority of workflow resource patterns, but for the moment we will simply assign roles to the various tasks and apply the System-User-User interaction strategy.

3.4.2 Modelling Data Requirements

We now need to specify what data will be passed about during the execution of an instance of this specification. Specifically, we need to describe what data participants will need in each work item, and what data they must return to the Engine once the work item is complete. We also need to have a way of moving data about in the running workflow, including how we can use that data to automatically choose between flows in a running workflow.

We stated before that task decompositions are used to define how a running workflow interacts with the external 'environment'. In fact, all nets of a YAWL specification along with all tasks that require interaction with the external environment need a decomposition. Decompositions can have a number of *parameters* (or variables) defined for them, describing what data must be supplied to a running net or task instance, and what data that net or task instance will eventually deliver. Each parameter has a *name* it may be referenced by, a *type* dictating valid values it may store, a *designation* indicating how that data may be used, and a *scope* defining the visibility of the parameter.

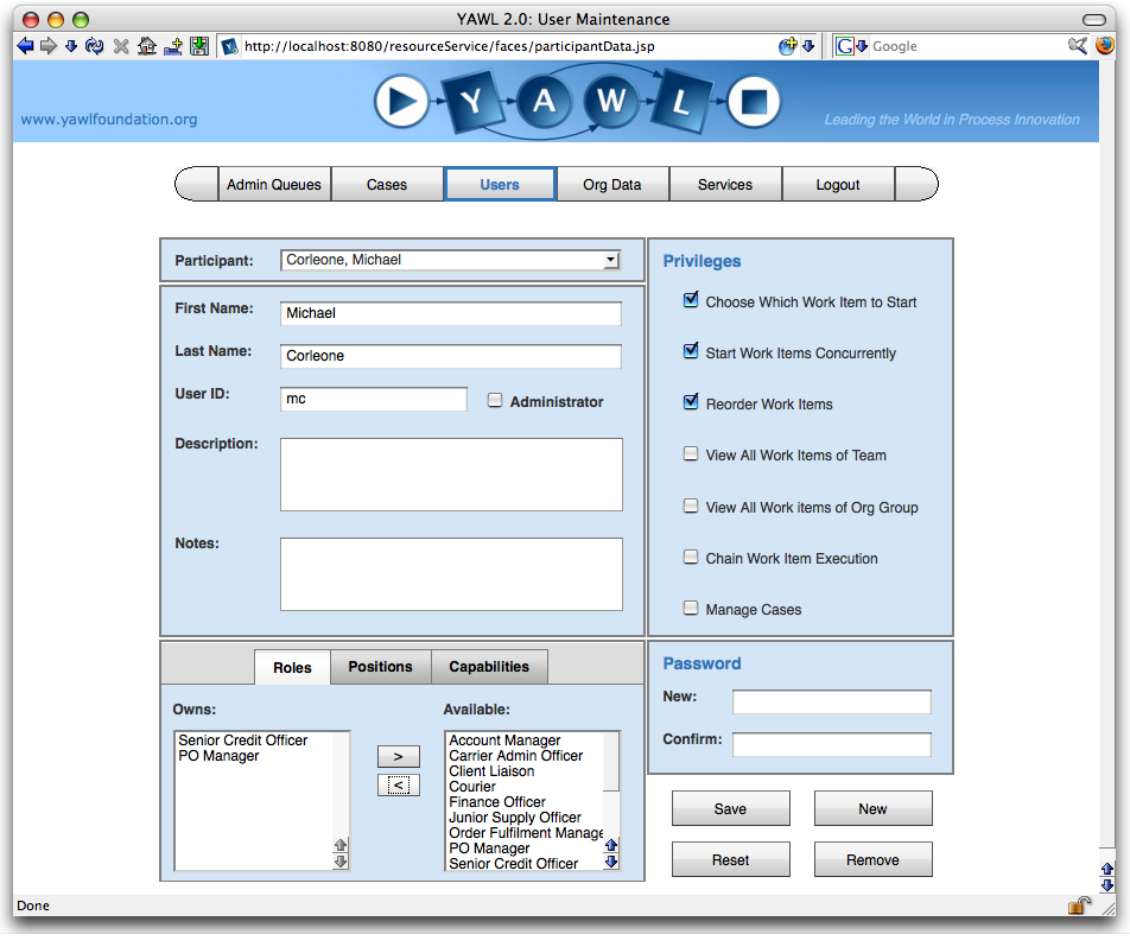


Figure 3.6: Defining a Participant

Parameters can belong to one of two scopes, which we'll refer to as *net scope* and *task scope*. At runtime, every net, and every task instance with a decomposition, will have data stored as a number of parameters belonging to it. To get data from a net instance to a task instance it contains, or visa-versa, we require a data transfer. In YAWL, all data is passed this way – from net-level to task-level when a task instance starts, and from task-level back to net-level when the task instance completes; data cannot be directly transferred from one task instance to another.

Valid designations for a task parameter are *input*, *output* or both *Input & Output*. A task parameter with an input designation is one where we expect data to be delivered from a net-level parameter to that parameter at run-time. A task parameter with an output designation it expected to have its data output to a containing net-level parameter once a task instance has completed.

Just like task parameters, net parameters may have *input* and/or *output* designations. A net-level input parameter requires its data value provided when the net begins. A net-level output parameter passes its value out when the net completes. In addition to these two options, net parameters may have a *local* designation. You can think of a net parameter with a local designation as a local variable. They are used to store intermediate data during the execution of a process instance.

Data transfer from a net a task is achieved via *inbound mappings*. An inbound mapping is a statement that says how to transfer data from the net's parameters to a task's input parameters. Inbound mappings are evaluated when the task starts. Conversely, once the task is completed, data is moved from the task's scope to the net scope by means of *outbound mappings*. An outbound mapping is a statement that says how to

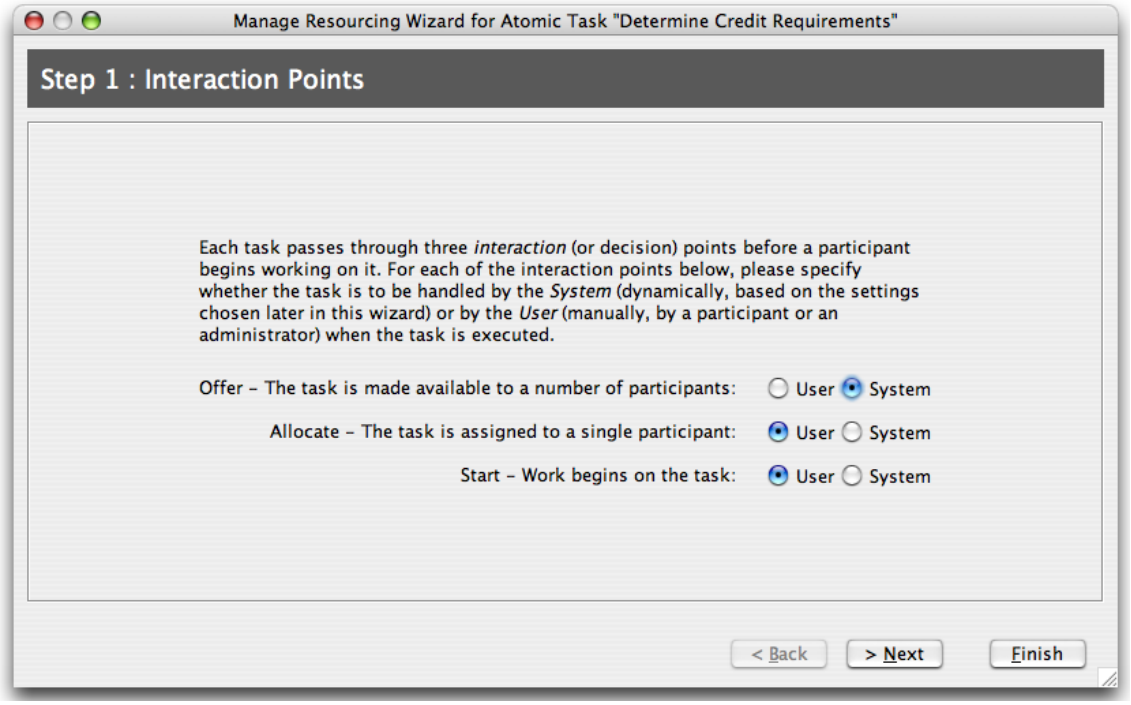

Manage Resourcing Wizard for Atomic Task "Determine Credit Requirements"
Step 1 : Interaction Points
Each task passes through three interaction (or decision) points before a participant begins working on it. For each of the interaction points below, please specify whether the task is to be handled by the System (dynamically, based on the settings chosen later in this wizard) or by the User (manually, by a participant or an administrator) when the task is executed.
Offer – The task is made available to a number of participants: User System
Allocate – The task is assigned to a single participant: User System
Start – Work begins on the task: User System
< Back
> Next
Finish

Figure 3.7: Specifying the Interaction Strategy

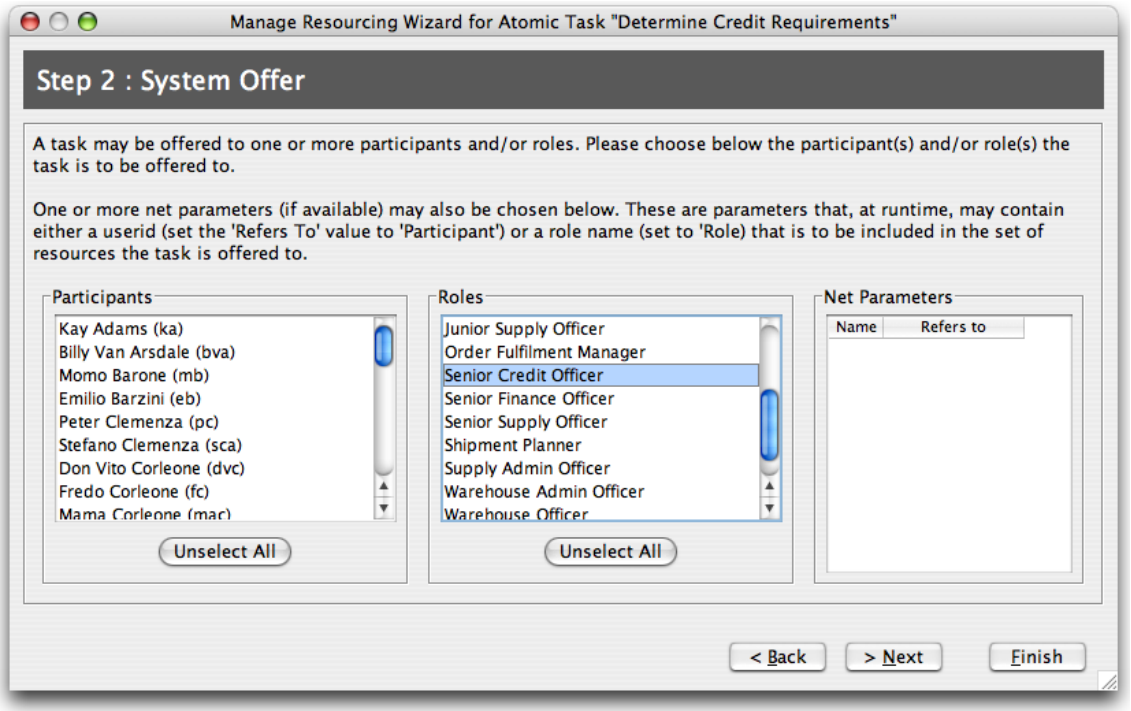

Manage Resourcing Wizard for Atomic Task "Determine Credit Requirements"
Step 2 : System Offer
A task may be offered to one or more participants and/or roles. Please choose below the participant(s) and/or role(s) the task is to be offered to.
One or more net parameters (if available) may also be chosen below. These are parameters that, at runtime, may contain either a userid (set the 'Refers To' value to 'Participant') or a role name (set to 'Role) that is to be included in the set of resources the task is offered to.
Participants
Kay Adams (ka)
Billy Van Arsdale (bva)
Momo Barone (mb)
Emilio Barzini (eb)
Peter Clemenza (pc)
Stefano Clemenza (sca)
Don Vito Corleone (dvc)
Fredo Corleone (fc)
Mama Corleone (mac)
Unselect All
Roles
Junior Supply Officer
Order Fulfilment Manager
Senior Credit Officer
Senior Finance Officer
Senior Supply Officer
Shipment Planner
Supply Admin Officer
Warehouse Admin Officer
Warehouse Officer
Unselect All
Net Parameters
Name
Refers to
< Back
> Next
Finish

Figure 3.8: Assigning a Role

move data from the task's output parameters to its containing net's parameters. XPath expressions[4] are

[4]For more advanced workflows, XPath expressions may prove too limiting. Accordingly, YAWL allows developers to also use XQuery expressions for data transfer in such cases.

used to describe inbound and outbound mappings. Accordingly, the parameters of nets and tasks in YAWL are all encoded as XML documents.

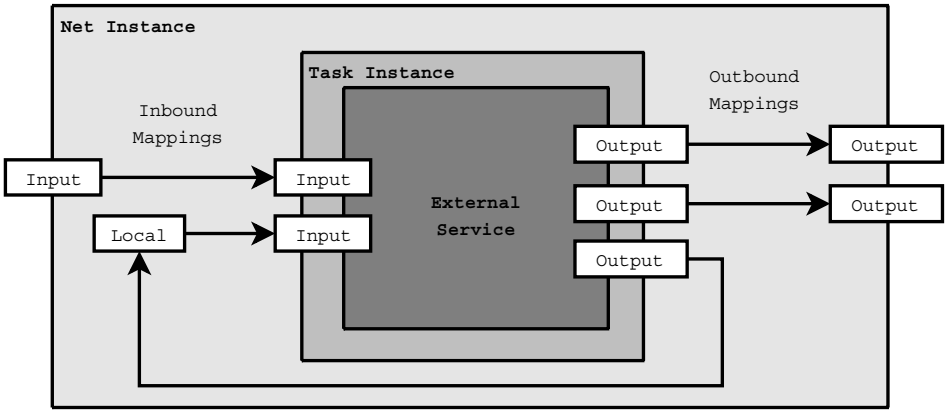


Figure 3.9: Example Data Transfer between a Net and Task

Figure 3.9 depicts example data transfers over the lifetime of a task instance. The task's decomposition defines two input parameters and three output parameters. When the task instance starts, values for its input parameters are populated by executing the input mappings for the task, which are then passed onto the task's designated YAWL Service. The default worklist handler is an example of an external service, but there are many others and advanced users are able to define and add virtually any service they want. The external service eventually finishes its execution, resulting in values being supplied to the output parameters of the task instance. The output mappings for this task instance are then executed, resulting in a number of parameters in the task's containing net instance being updated with values from the task instance's output parameters.

Now we have a basic understanding of data transfer in YAWL, let's start specifying the data transfer requirements of our workflow specification. Since all data are passed as XML documents, all data types are defined using XML Schema Language – there are over 40 in-built XML Schema data types, and YAWL allows users to also define their own). For our example, will limit our parameters to be of either XML Schema *string* or *double* simple types. We'll go through our atomic task decompositions now and add parameters to each task decomposition first before we add the necessary data transfer mappings for moving data between tasks and their containing net.

Imagine that we have finished an exercise of determining what data must be passed out of YAWL at the starting of each task of our specification, and what data must be returned back into the system when each task completes. We note through the exercise that even though the tasks *Large Credit Approval* and *Small Credit Approval* are done by different parts of the organisation, they have the same data requirements, and can both use the same decomposition (which we'll call *Credit Approval*). We have a resulting parameter requirement per decomposition as per figure 3.10.

Decomposition	Param-Name	Type	Designation
Receive and Validate Application	ApplicationID	string	output
Determine Credit Requirements	ApplicationID	string	input
	ApplicationAmount	double	output
Obtain Credit Report	ApplicationID	string	input
	CreditReportRef	string	output
Credit Approval	ApplicationID	string	input
	CreditReportRef	string	input
	ApplicationAmount	double	input

Figure 3.10: Parameters Required for Task Decompositions

To give you some idea of how this might look, figure 3.11 is a screenshot of the Editor showing the decomposition for the task *Determine Credit Requirements* with an input parameter *ApplicationID*, and an output

parameter *AppplicationAmount*. When running our specification, a participant will be offered a work-item for an instance of this task. They will be given an application identifier, and will work outside of the system, eventually generating an application amount for that application. Figure 3.12 shows how the default worklist handler displays an instance of this task for a participant to work with.

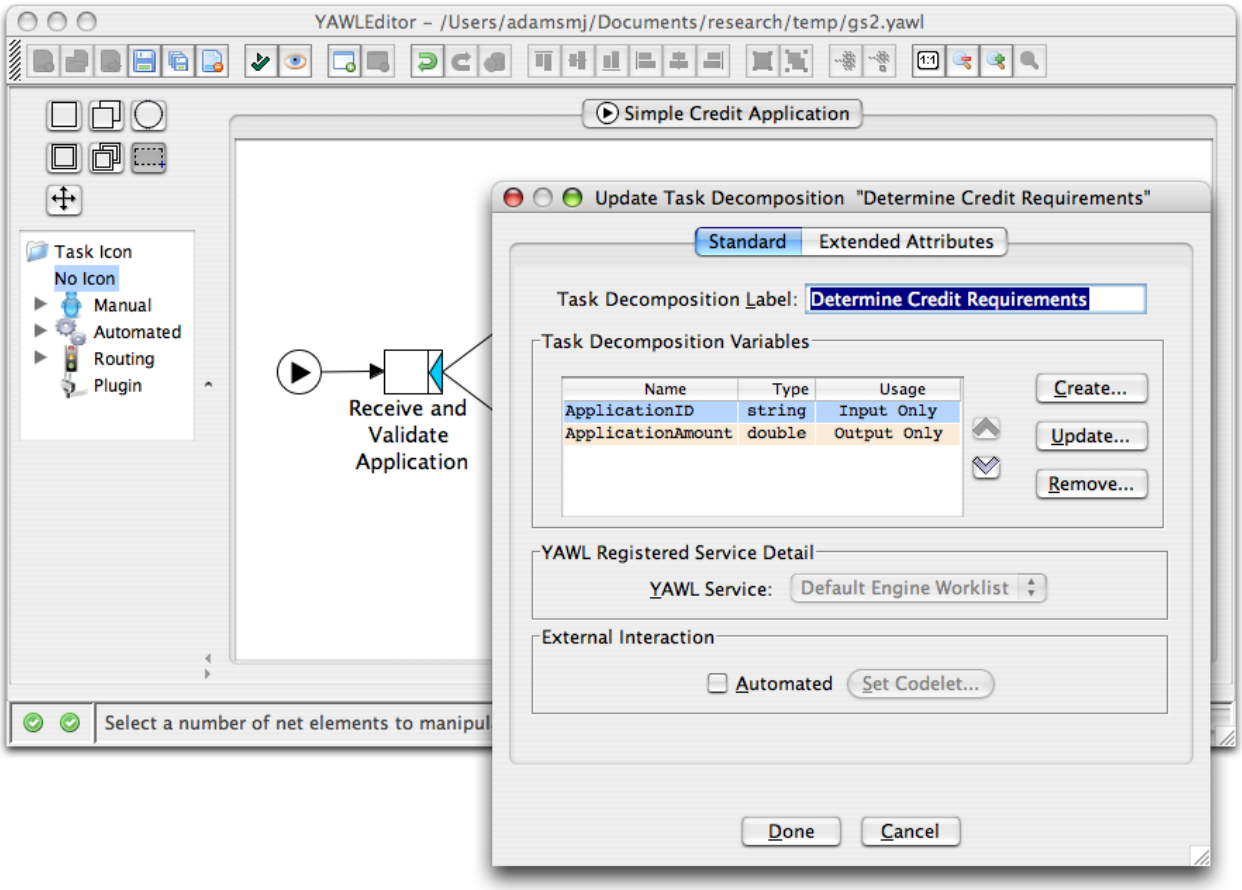


Figure 3.11: Establishing Parameters on a Task Decomposition

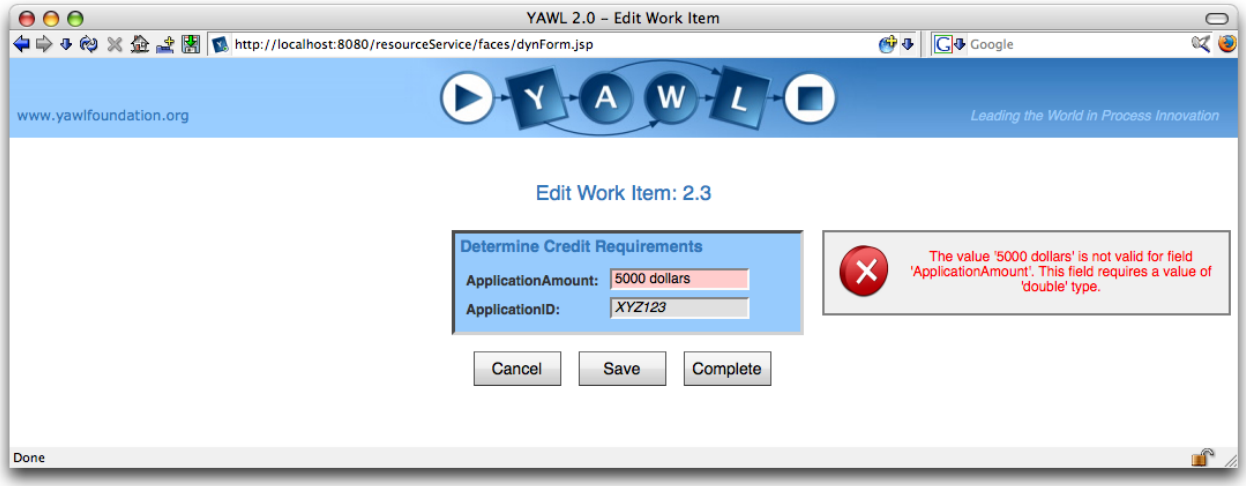


Figure 3.12: A *Determine Credit Requirements* work-item shown on a dynamic form

Attaining an application amount may be as trivial as reading the number from the relevant form, or as involved as considering the business's current risk exposure, running calculations, and adjusting the figure to something the insurance company is more willing to accept. The exact nature of the work to be done is left to the participant and the business rules of the organisation, and only that data relevant to progressing the workflow needs to be passed back into the system once they are done.

Because we can't transfer data directly between tasks, we're also going to need a number of *local parameters* for the decomposition of our starting net. Specifically, we'll need matching *ApplicationID* and *ApplicationAmount* local parameters at the net level, and another called *CreditReportRef* that will be used by a couple of other tasks in the workflow.

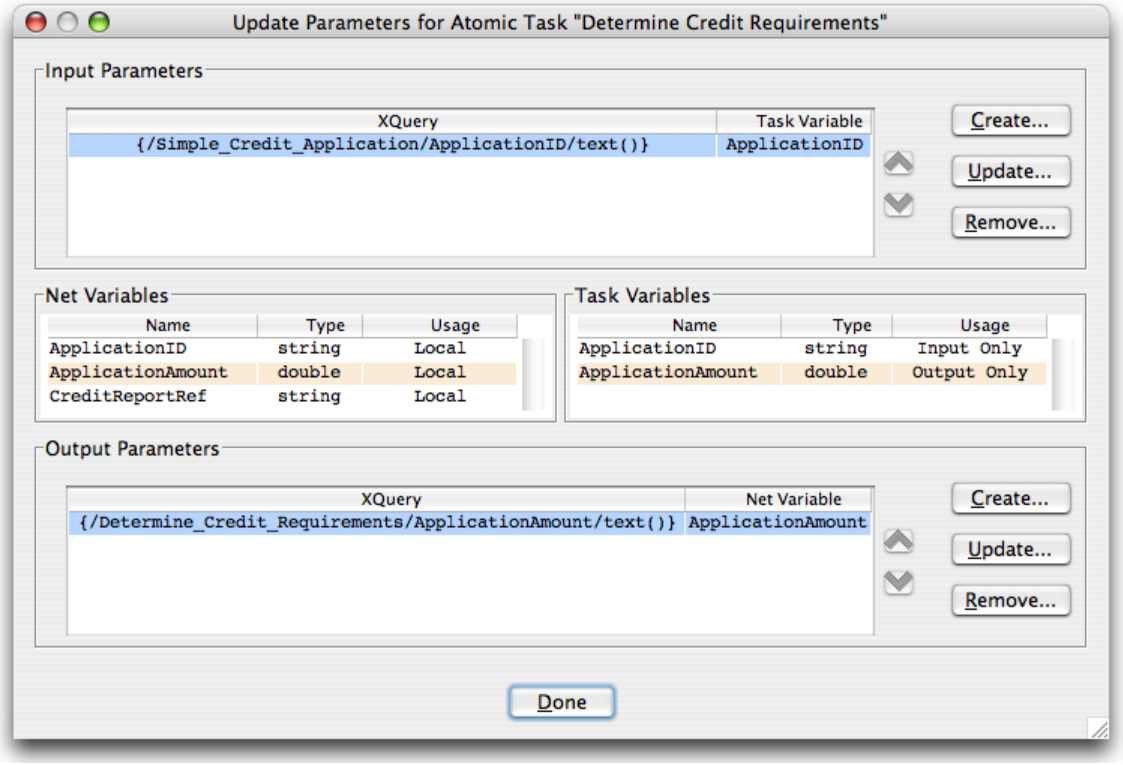


Figure 3.13: Data Mappings for *Determine Credit Requirements* Parameters

With these local net parameters in place, we now need to specify how data is passed between the net and tasks with XPath expressions. The XPath expressions needed are fairly straightforward. For a task input parameter, we need the expression to fetch and populate the value of this parameter with that of its corresponding net parameter. For a task output parameter, the matching net parameter needs an expression to retrieve the value of the task parameter. Figure 3.13 shows an example of the queries needed for the *Determine Credit Requirements* task (note that XPath expressions of this kind are generated with a couple of mouse clicks in the Editor). A similar exercise can then be conducted for the parameters of the remaining tasks.

The only thing remaining to do with data in our specification is to deal with the XOR-Split. XOR-splits need a boolean XPath expression to be associated with each outgoing flow of the split[5]. These expressions are evaluated once a task instance completes. Thus, the expressions can only interrogate the state of a net that a recently completed task has updated. Expressions that evaluate to true indicate that a flow is to be taken. In the case of an XOR-Split, the flows have an ordered priority specified. The first flow in order whose XPath expression evaluates to true will be the only flow taken from a completed task.

The only task we need to consider in this regard is *Choose approval process*. Consulting our transcript again,

[5]Each XOR-split and OR-split has one flow specified as the default, and is assumed to always have *true* value, to ensure that the workflow can continue even when all other flow conditions evaluate to false.

approval amounts of less than $5000 are to be routed to the *Small Credit Approval* task. Anything more requires *Large Credit Approval* to be run. The XPath expressions needed to capture this choice are shown in Figure 3.14. Once this is specified, we are done. We have a workflow specification that ensures the right work and data gets routed to the right participants at the right time.

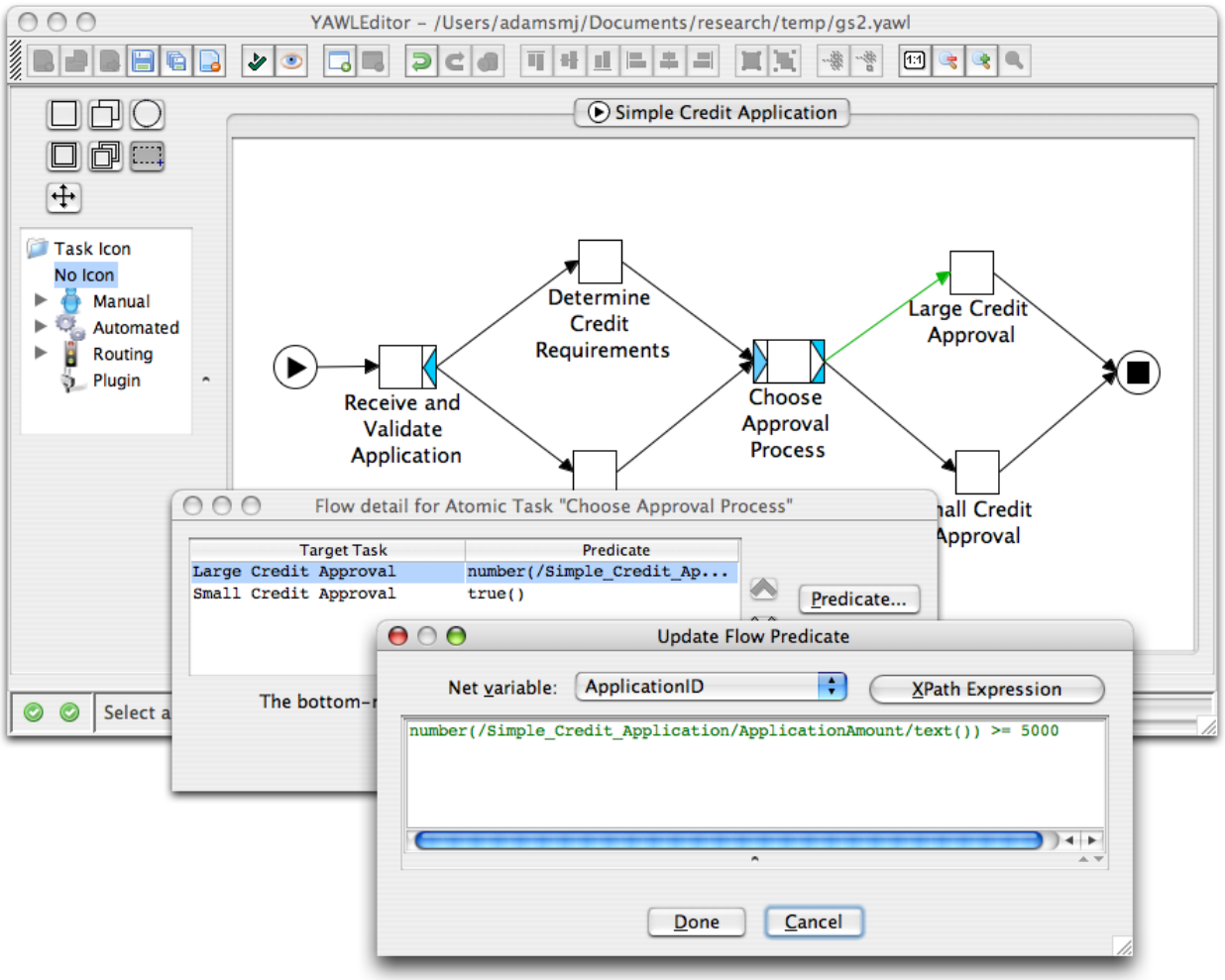


Figure 3.14: XPath predicates to choose between flows of an XOR-Split task

3.5 Where To From Here

You've now seen how we can construct a workflow specification for YAWL. We've used atomic tasks, with various types of splits and joins, along with resourcing and data requirements to implement a simple credit application processing workflow specification. But, we have so far only scratched the surface of what can be achieved with YAWL.

What you haven't seen yet is how larger workflows can be constructed by binding a number of nets together with composite tasks. We are also capable of iterating through a number of instances of a single task using Multiple Instance Task constructs. A single task can also be used to trigger the cancellation of current work in other parts of the workflow, which might be used for modelling a customer calling and cancelling an order that is currently being processed. Finally, we haven't described *conditions*, which represent the state a workflow is in after one task is finished but before another starts. Conditions allow us to model two or more participants competing for the same work, or a user making a decision on things that workflow

systems cannot not automatically determine. An example of this would be asking a participant to decide on whether the aesthetics of some partially assembled work are appealing or not, and having the workflow coordinate further work based on that choice.

What we've also glossed over here is how to actually use YAWL's toolset. We have used version 2.0 of the Editor and of the Engine for the screenshots in this chapter. The components of YAWL can all be found at Sourceforge, via the URL http://sourceforge.net/projects/yawl/. Further explanations of the use of this environment can be found in the remainder of this user manual, while there is also a *technical manual* for those that want to develop more complex applications. A number of case studies documenting the use of YAWL are also available. Mailing lists and forums around the components of YAWL can also be accessed via this Sourceforge URL. And as mentioned earlier, YAWL is the product of several years of research into workflow patterns and formal foundations of workflow. This research, along with other informative material is available via the URL http://yawlfoundation.org/.

Chapter 4

The Editor

Before a workflow model can be executed it must first be defined. This chapter describes the YAWL Editor (version 2.1), a tool for creating, editing, configuring, validating and analysing workflow specifications. New users are encouraged to read the chapter sequentially; experienced users may pick-and-choose what they need from this chapter.

Figure 4.1 illustrates the interactions among some of the major components of the YAWL environment.

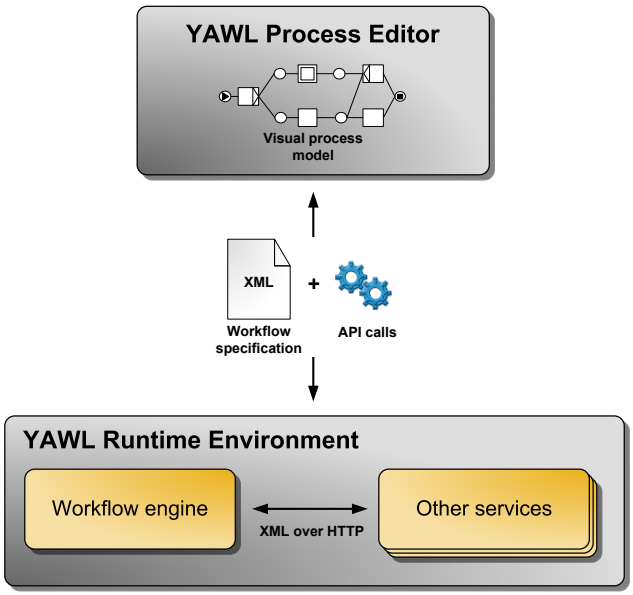


Figure 4.1: The YAWL Components

In this chapter, this icon indicates a hands-on method or instruction.

4.1 Launching the YAWL Editor

The Editor is installed along with the other YAWL System components using any of the installers described in Chapter 2. It can also be installed manually by downloading the latest version from the YAWL SourceForge website: http://sourceforge.net/projects/yawl/. Be sure that the version number of the Editor you are using matches the version of YAWL installed.

The YAWL Editor is distributed as a Java Archive (jar). Double click on the *YAWLEditor2.2.jar* file to start

the application (where supported). The YAWL Editor can also be started from a command line or Terminal prompt:

java –jar YAWLEditor2.2.jar

4.2 The YAWL Editor Workspace

The first time you start the YAWL Editor, you will be presented with a blank canvas, and a prompt in the Status Bar advising you to open or create specification to begin.

Before you create your first specification, let us take a brief tour of the Editor's workspace and the elements within (the use of each element is fully described in later sections). The workspace is shown in Figure 4.2.

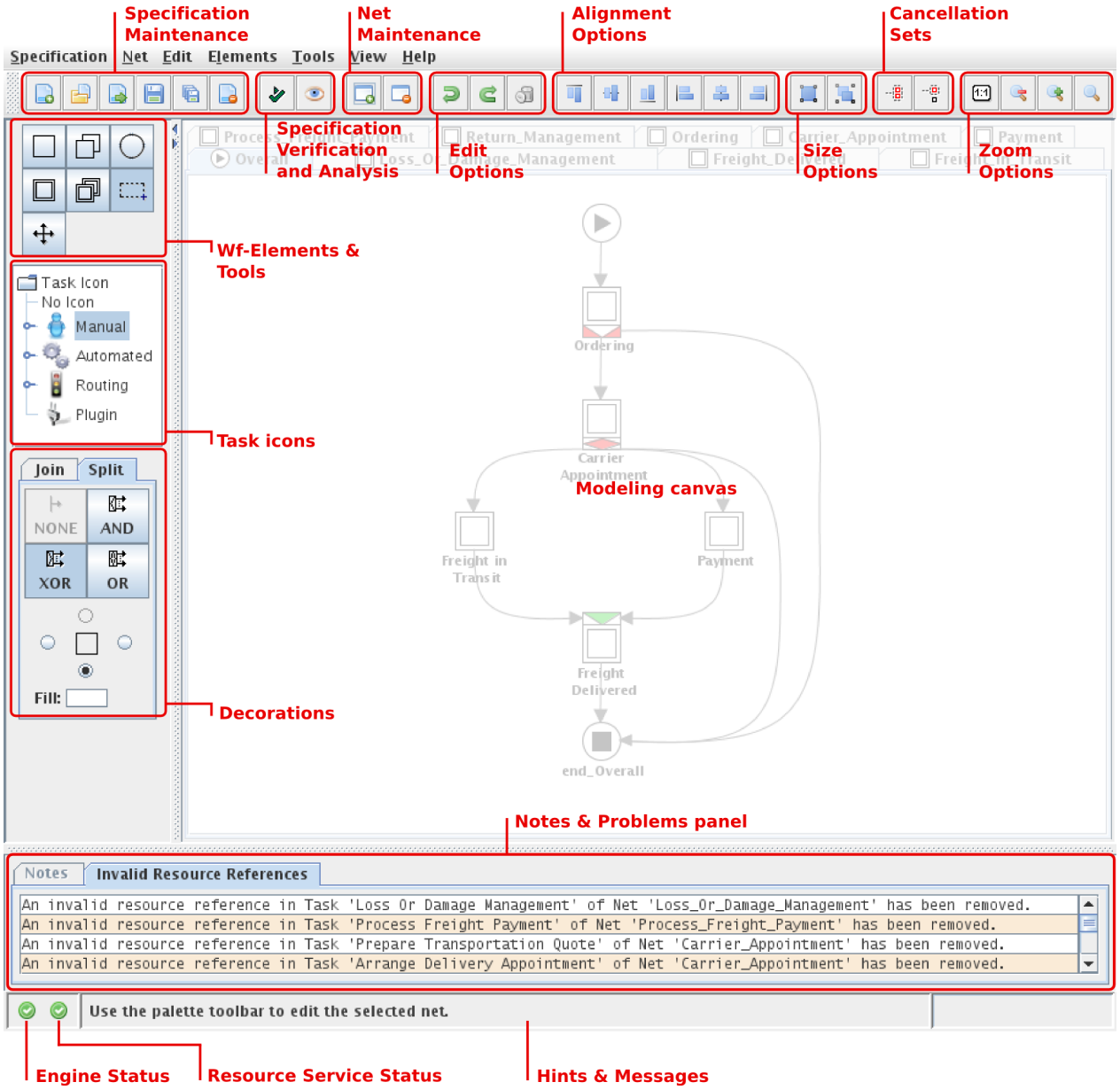


Figure 4.2: The YAWL Editor Workspace

4.2.1 The Toolbar

The Menu Toolbar contains nine groups of buttons to assist you in maintaining your YAWL specification. The toolbar can be repositioned by dragging the left-hand anchor bar. Each button may be enabled or disabled at certain times depending on what you are currently doing in the Editor.

Specification Maintenance

This group of buttons provides the standard file options (left to right):

- Create a new specification;
- Open an existing specification file. Specification files will have a **.yawl** extension (or sometimes a .xml extension, if they are an 'engine' file created with a pre-2.0 Editor version);
- Import a specification file created with a pre-2.0 version of the Editor. These files have a **.ywl** extension.
- Save the currently loaded specification to file. For newly created specifications, this behaves the same as *Save As*;
- Save As a new file name;
- Close the loaded specification. If there are any unsaved changes, you will be prompted to save the file first before closing.

Specification Verification & Analysis

The first of these two buttons allows you to validate your specification against YAWL syntax and semantics, while the second allows you to analyse your specification for deadlocks and other issues.

Net Maintenance

Each workflow specification consists of one or more nets. You can use these buttons to add a new Net to or remove an existing Net from your specification.

Edit Options

This group of buttons provides the standard Undo and Redo options as well as the option to delete the currently selected object(s).

Alignment Options

These buttons can be used to assist with the alignment of objects within your specification, when multiple objects have been selected. Left-to-right, they allow you to align selected objects based on:

- top edges;
- centres horizontally;
- bottom edges;
- left sides;
- centres vertically;
- right sides

The first selected object is used as the reference to align the other objects to.

Object Sizes

To increase or decrease the size of an object or objects within your specification, select the object(s) and then use these buttons.

Cancellation Sets

These buttons allow you to include in and/or exclude elements from the cancellation set of a task.

Process Configuration

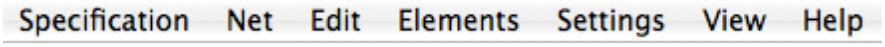
These buttons allow you to preview (left) and apply (right) process configuration settings for a net.

Zoom Options

These buttons allow you to apply zoom functionality to the currently selected net. From left-to-right, reset the zoom to the actual size, zoom the entire net out, zoom the entire net in, and zoom into the currently selected net elements. You may also zoom in and out on the currently selected net by holding down the Shift key and using the mouse wheel, while holding down the Shift + Ctrl keys and using the mouse wheel will scroll the net's view left and right.

4.2.2 The Menubar

This section provides a brief overview of the YAWL Menus located along the top of the YAWL Editor. The majority of menu choices are also available via the menu toolbar.



Specification

In addition to the Specification Maintenance, Verification and Analysis toolbar items, this menu also contains these sub-items:

- *Open Recent*: show a list of the eight most recent specifications loaded or saved in the Editor, so that one can be selected to be opened, saving the trouble of navigating to it via the file open dialog. If you hover the mouse over a listed file for a moment, a tip will appear showing the file's full path;
- *Print*: prints the entire loaded specification (graphically);
- *Update the Specification Properties*: such as specification name, author, description and so on;
- *Update Datatype Definitions*: where you can define your own data types to be used in the specification.
- *Delete Orphaned Decompositions*: allows you to permanently remove decompositions that are no longer attached to any task.

Net

In addition to the Net Maintenance toolbar items, this menu also contains these sub-items:

- *Set Starting Net*: for specifications containing several nets, this item allows you to specify which of them is the starting net (i.e. the net that begins execution of the workflow instance);
- *Update Net Detail*: shows a dialog where you can set the name of the net, and create/update/remove net-level variables;
- *Export to PNG Image*: saves a graphical image of the net to a file;
- *Set Net Background Colour*: set the background colour of the selected net;
- *Set Net Background Image*: set the background image of the selected net;
- *Print Net*: prints the currently selected net (graphically).
- *Process Configuration*:a sub-menu containing three items:
  - *Preview Process Configuration*: shows a preview of the effect of the current process configuration settings;
  - *Apply Process Configuration*: applies the current configuration settings to the net, so that only the configured components remain;
  - *Check Configuration Correctness*: analyses the net to check the correctness of configuration settings (requires that the 'wendy' tool is available).

Edit

In addition to the Edit Options toolbar items, this menu also contains sub-items to Cut, Copy and Paste objects to/from the canvas.

Elements

This menu contains the Alignment Options, Object Sizes and Cancellation Set toolbar item sets. You can also set the fill colour for all selected tasks and conditions using this menu.

Settings

This menu contains the following items:

- *Engine Connection*: The Editor must connect to a running Engine to obtain a list of the available services that a task can be assigned to (amongst other things discussed in later sections). This menu item allows you to set the parameters for a connection to the Engine and to proceed with a connection.
- *Resource Service Connection*: The Editor must connect to a running Resource Service to obtain a list of the available resources that task can be allocated to (amongst other things discussed in later sections). This menu item allows you to set the parameters for a connection to the Resource Service and to proceed with a connection.
- *Specification Analysis*: This item will display a dialog where various verification and analysis techniques may be chosen. In addition, if the **wofyawl** analysis utility is available, the configuration dialog will allow process designers to configure and use wofyawl for additional specification analysis[1].
- *Process Configuratio*n: This item will display a dialog where the desired process configuration settings may be chosen.
- *External File Paths*: This item will display a dialog where the disk locations of the following components may be specified:
  - User-defined extended attributes for decompositions;
  - User-defined extended attributes for variables;
  - User-supplied icons for tasks;
  - the WofYAWL tool (for specification analysis);
  - the Wendy tool (for process configuration).

View

You can use this menu to toggle:

- Tooltips, which provide useful hints when your mouse is positioned over various items;
- Anti-aliasing of graphical components; and
- Grid on the canvas background – useful for aligning objects visually.

This menu also provides options to set the font size used for element labels, the default background colour for nets, and the default background colour for elements (i.e. tasks and conditions). Finally, it shows a list of all the nets of the loaded specification, allowing the selection of one from those available for editing.

Help

The Help Menu provides an "About the Editor" dialog, describing components used in the editor's construction, a list of source code contributors, and the version and build date of the Editor in use.

4.2.3 Workflow Elements and Tools

The Workflow Elements and Tools panel contains seven selectable buttons – five YAWL language icons and two selection tools – that assist with creation, selection and positioning of objects within your specification. This panel is also accessible by right-clicking on any blank area of the canvas.

Once an element is selected, it is possible to place objects of that type on the canvas by left-clicking the mouse button at the desired location.

[1] Only available when installed in a Windows environment.

Atomic Task

Select this button to create an Atomic Task, which represents a single task to be performed, usually by a human participant or an external application or service.

Composite Task

Select this button to create a Composite Task, which is a container for another YAWL (sub) Net - with its own set of YAWL elements constrained by the same syntax.

Multiple Instance Atomic Task

Select this button to create a Multiple Instance Atomic Task, which allows you to run multiple instances of a task concurrently.

Multiple Instance Composite Tasks

Select this button to create a Multiple Instance Composite Task, which allows you to run multiple instances of a composite task concurrently.

Condition

Select this button to create a Condition, which is a way to represent state for the Net.

Marquee Selection

Select this button to activate the Marquee Selector, which will allow you to select individual or multiple objects by clicking and dragging the left mouse button. Note: you cannot create flows (arrows between tasks) while the Marquee Selector is selected.

Drag Net Window

Select this button to drag the visible window of a net around that net.

4.2.4 Other Components

The Canvas

The Canvas is where elements are placed to create and modify a workflow specification.

Task Icons Panel

This panel shows a set of icons that can be selected and placed on the tasks of your specification to add visual cues that aid in the understanding of your models by others. The Editor comes with a standard set of icons, and you may also provide your own icons and access them via this panel. Note that the icons are grouped for ease-of-use only; you are not limited in how you actually use the icons in your model. Any icons displayed have no bearing on how the model executes at runtime.

Decorations Panel

The Decorations panel provides a set of decorator types that may be attached to a task. You can select the type of decorator, what edge it is to be positioned on the task and choose a colour to use for each decoration.

Notes and Problem Panel

This panel consists of two tabs:

- On the *Notes* pane, you can add freeform text to accompany the selected task or condition. Any text entered is accessible only at design time;
- The *Problems* pane will list problems or messages that may occur while you are building your model, when you validate it or when you analyse it.

Status Bar

The Status Bar consists of three parts:

- On the left are two icons that indicate whether there are currently valid connections to the Engine and the Resource Service (required for certain design activities discussed later in this chapter). A connection will show a green indicator, a disconnection as a red indicator;
- Next there is a status message area that provides useful contextual hints throughout the creation of your specification;
- On the right is a progress bar, which shows the progress of various events at different times.

4.3 Creating Your First Specification

Overview

This section will lead you through the process of creating a YAWL specification from beginning to end, through a series of brief lessons following a scenario.

You can either follow all the instructions including the scenario provided, from beginning to end, or skip straight to the section that you are interested in and follow the instructions.

Look for the student icon next to the instructions for specific details of the scenario.

The Scenario

The scenario that we will be following throughout this section is the workflow of a student who has just completed their secondary study and is now looking to start their career. The scenario will follow the path of a student who either enrols in a University to complete their tertiary education, or undertakes private study that will eventually lead them to getting a job and starting their new career.

4.3.1 Creating Your First Specification

1. Click on the Create a New Specification button, , at the top left of the Menu Toolbar, or click on **Specification** in the Menu and choose **Create Specification**. This will create a blank Net called "New Net 1" which will be, by default, the starting net of the workflow. For details on selecting a starting net, see Section 4.3.6.

2. Click on **Specification** in the main Menu and choose **Update Specification Properties**. A screen as per Figure 4.3 will appear. Alter the specification's properties as you feel appropriate (optional).

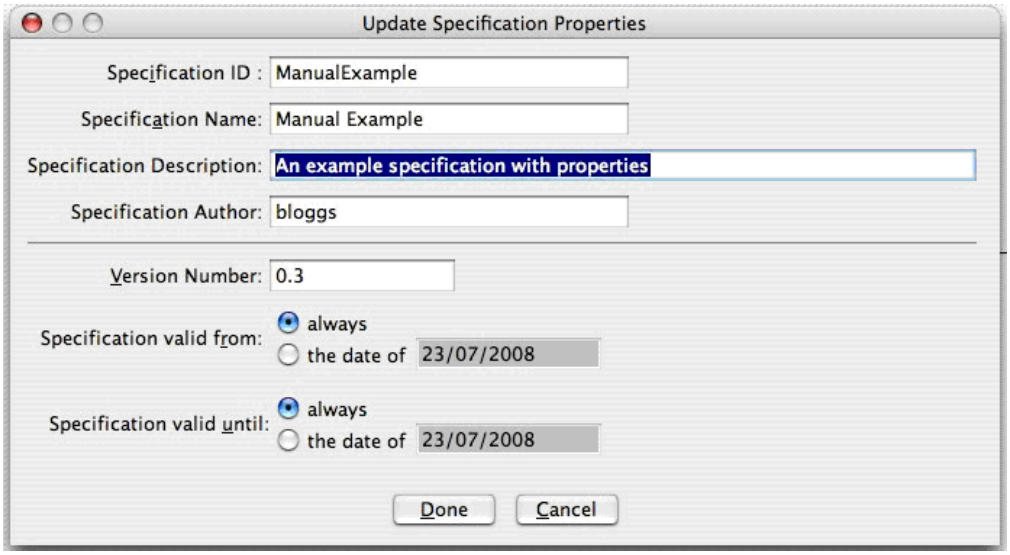


Figure 4.3: Specification Properties Dialog

3. Rename this Net by clicking on the **Net** Menu and choosing **Update Net Detail**.

4. Enter the new name of the Net in the "Decomposition Label" field, then click the **Done** button.

   Decomposition Variables will be explained later in Section 4.5.3.

   Change the name of the Net in the Decomposition Label, to "My Career". This Net will be the primary net for our scenario.

5. You are now ready to start drawing your specification.

4.3.2 Atomic Tasks

1. Click on the "Add an Atomic Task" button, , in the Workflow Elements Panel, or right click in an empty area of the canvas, and choose **Atomic Task**.

2. Position your mouse just to the right of the Input Condition (the ▶ symbol), and click the left mouse button once to place an Atomic Task.

3. Set the decomposition of this task by right clicking on the Atomic Task and choosing **Select Task Decomposition**. You should see a dialog as per Figure 4.4.

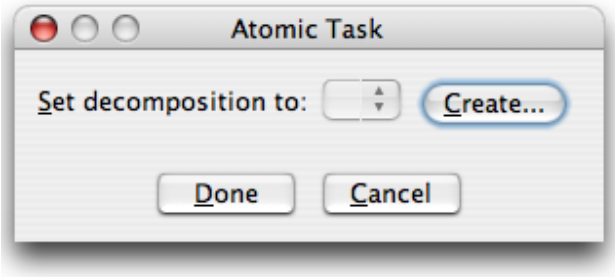


Figure 4.4: The "Select Task Decomposition" dialog

4. Press the **Create...** button, and in the following *Update Task Decomposition* dialog, enter the decomposition's label.

   See Section 4.5.5 for a full explanation of this dialog's features.

   Set the label to "Begin My Career", and click the **Done** button.

5. Note that by default, a task takes on the label of the decomposition that it is associated with (several tasks are allowed to share the same decomposition). Once you've created your task, you are free to relabel the task to whatever you like. This can be done by right-clicking on the task and choosing **Set Label...** from the pop-up menu. This will not change the name of the decomposition with which the task is associated.

6. Connect the Input Condition to your Atomic Task, as shown in Figure 4.5, by finding the flow connectors that appear as small blue boxes as you hover your mouse over the sides of the objects. Hold the left mouse button down over a flow connector and draw a line by dragging the mouse from the flow connector on the Input Condition to the one on the Atomic Task (which will appear when the mouse hovers over the edges of the task). The editor will only show a connection point if it is valid to draw a flow connection between the objects. The directed arc (arrow) between two objects is referred to as a

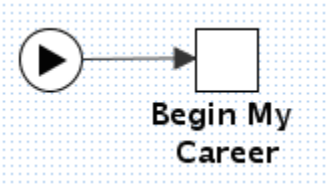


Figure 4.5: An established flow relation

   flow relation, or most often simply a *flow* – it shows the 'flow' of execution from one object in the net to the next. That's it! Your Atomic Task is set.

   Repeat the process for the following Atomic Tasks in order: Go to University, Get A Job, Career Started.

   Link the 'Career Started' task to the Output Condition (the ■ symbol), as per Figure 4.6.

7. Finally check the validity of specification by clicking on the Validate Specification button, , in the Menu Toolbar or click on **Specification** in the Menu and choose **Validate Specification**. If all things

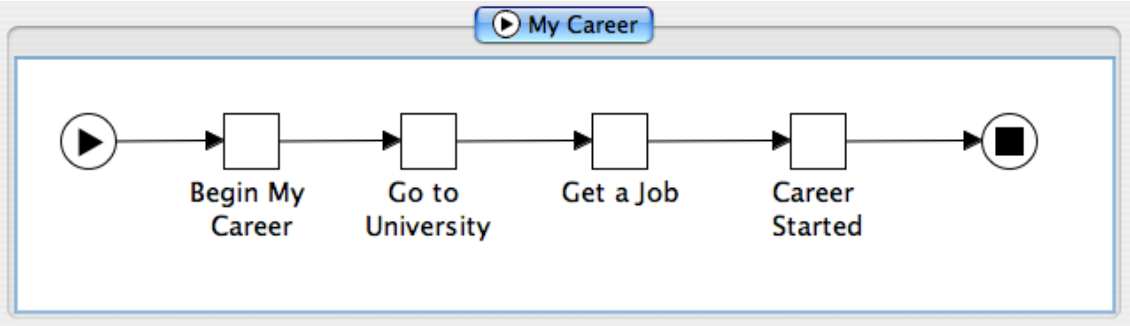


Figure 4.6: The "My Career" Net

are going to plan, then you will receive a confirmation message in the Notes panel at the bottom of the Editor saying that there were no errors detected.

Task Indicators

Task indicators are mini-icons that appear across the top of a task to provide a visual cue regarding settings that have been applied to the task. An example of a task with all three available indicators is shown in Figure 4.7.

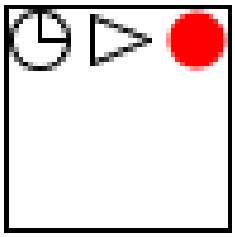


Figure 4.7: Task Indicators

The three task indicators (left to right in Figure 4.7) are:

- **Timer**: This task has had a timer set (see Section 4.12).
- **Automated**: This task has been set as automated (see Section 4.10). If this automated task also has a codelet specified, it will be filled green (see Section 4.10.1).
- **Cancellation Set**: This task has had a cancellation set defined (see Section 4.5.1).

These task indicators are rendered on top of any icons set for the task.

Task Decoration

Decorating a task is the process of adding a split and/or join to the task.

By adding a split decorator to a task, you are specifying that when the task completes, it will be succeeded by one or more tasks. Here are the possible choices for a task's split decorator:

- No split: The task has no split decorator, and so will have exactly one outgoing flow;
- AND split: The task may have a number of outgoing flows; when the task completes, it will activate *each and every* outgoing flow;

- XOR split: The task may have a number of outgoing flows, each with an associated condition; when the task completes, it will activate *exactly one* outgoing flow – the first that has its condition evaluate to true, or the designated default flow if none of the other flow conditions evaluate to true;
- OR split: The task may have a number of outgoing flows, each with an associated condition; when the task completes, it will activate *each* outgoing flow that has its condition evaluate to true, or the designated default flow if none of the other flows evaluate to true;

By adding a join to a task, you are specifying at what point the task will become available for execution through the completion of one or more preceding tasks flowing into it (depending on the type of join). Below are possible choices for a task's join decorator:

- No join: The task has no join decorator, and so will have exactly one incoming flow;
- AND join: The task will activate only after *each and every* incoming flow is activated (through the completion of the task at the other end of each flow);
- XOR join: The task will activate as soon as *one* incoming flow is activated (through the completion of the task at the other end of the flow);
- OR join: The task will activate only after each and every incoming flow *that can possibly be activated* has activated. Basically this means the completion of each and every task at the other end of a flow leading into the OR-join that has started or may possibly start at some future time. More on the OR-join in later sections.

For more detailed information on join and split types, please consult the YAWL technical papers on the YAWL website.

Creating Splits and Joins

To create a split or join:

1. Select a task. When a single task is selected the Decorator panel will appear with two tabs that allow you to decorate a task with a split and/or join. You can also choose a fill-colour to help visually differentiate splits from joins with the expanded colour palette.
2. Choose the required split or join and the orientation (which edge of the task to attach the decoration to) for the split or join to appear.

   In our example, select the "Begin My Career" task and, in the Decorator panel, select an **XOR** split. Then set the orientation to eastern edge of the task, as per Figure 4.8.

   Create a new Atomic task called "Do Private Study". This task will represent those students that choose not to go to University.

   Finally, select your "Get A Job" task and decorate it with an **XOR** join. Then set the orientation of the join to the western edge of this task.
3. Split and Join decorators allow you to connect several Flow Relations from and to your task respectively.

   Create a flow relation from "Begin My Career" to "Do Private Study", then create another flow relation from "Do Private Study" to "Get A Job", as per Figure 4.8.
4. Don't forget to check the validity of your specification.

Hint: If you are having trouble with positioning your tasks, the alignment tools are a big help.

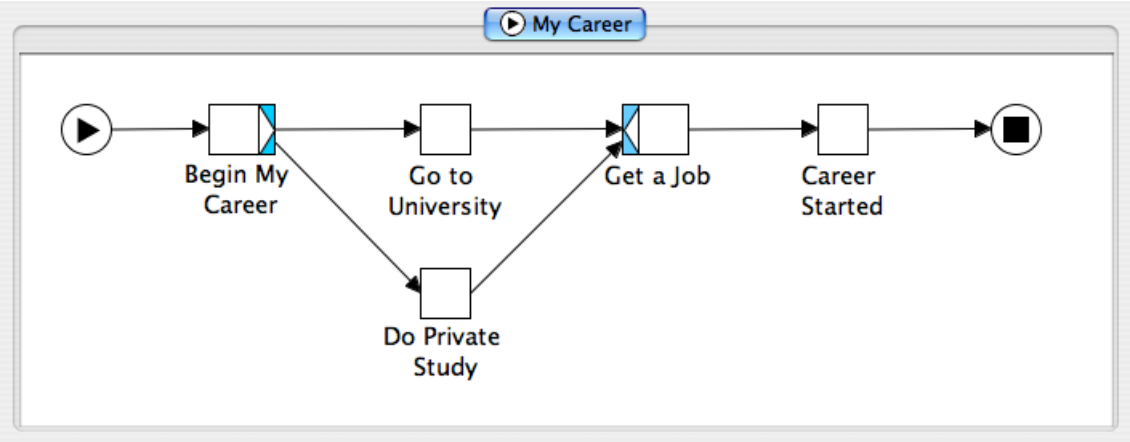


Figure 4.8: XOR Split and Join

When "Begin My Career" has been completed, a choice must be made on which of the two tasks ("Go To University" or "Do Private Study") will be followed (XOR Split). How that choice is made will be explained a little later. "Get a Job" will become available after the completion of the task selected at the point of the XOR split.

Composite Tasks

1. Composite tasks are placeholders for other sub-nets. That is, you can create another workflow in a separate Net, which is represented in the first net by the composite task. When a composite task is activated, control branches to the sub-net; when the sub-net completes, control passes back to the parent net.

2. To create a Composite Task: click on the Composite Task button, , in the Elements panel or right click on an empty part of the canvas and choose **Composite Task**.

   We are going to replace our existing "Go to University" Atomic Task with a Composite Task, so click on the "Go to University Atomic Task" and click the trash bin on the toolbar or press the Delete key on the keyboard. We will add in the new composite task next.

3. Place your Composite Task in your Net. *Tip: use the arrow keys on your keyboard to move/adjust the task to the desired location.*

   Reconnect the Flow Relations from "Begin My Career" to the new Composite Task, and from new Composite Task to "Get a Job".

4. Create a new Net by clicking on the Create a New Net button, , on the Menu Toolbar, or click on the **Net** Menu and choose **Create Net**.

5. Choose a name for this Net by clicking on the **Net** Menu and choosing **Update Net Detail**.

   We are going to call this new Net "Attend University".

6. Return to your original Net and right click on your Composite Task and choose **Unfold to net...**. You will then be given a drop-down list with all the Nets available – choose the Net this task is to represent and then click **Done**.

   *Tip: you can also combine the last three steps by simply right clicking on the newly added composite task, selecting **Unfold to net...**, then clicking the "Create" button in the dialog that appears.*

Choose “Attend University”.
You can now fill out the detail of your new ”Attend University” Net.

Create the following Atomic Tasks in order and then link them with Flow Relations and don’t forget to check for validity:

- Enrol
- Do Subjects
- Pass All Subjects
- Get Degree

The resulting nets are shown in Figures 4.9 and 4.10.

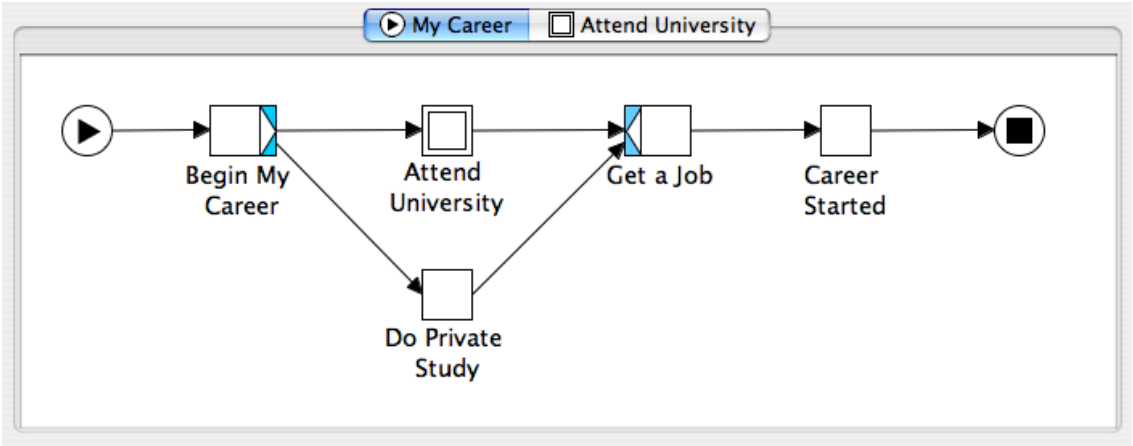


Figure 4.9: Parent net with “Attend University” Composite Task

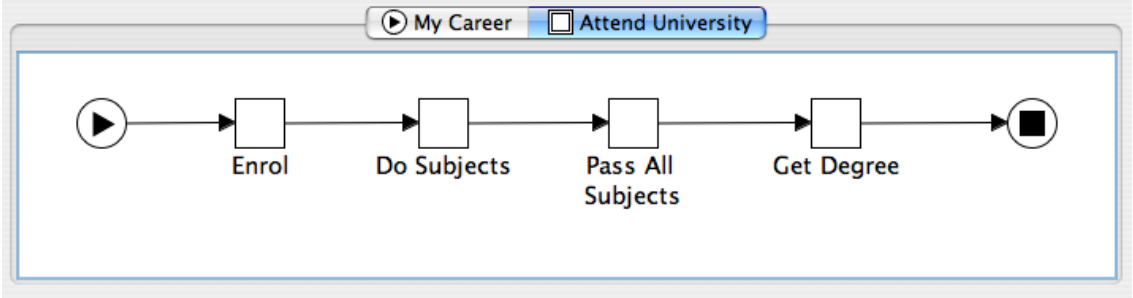


Figure 4.10: The “Attend University” sub-net

4.3.3 Multiple Instance Atomic Tasks

Multiple Instance Atomic Tasks (MI Tasks) allow you to run multiple instances of a task concurrently.
To create a Multiple Instance Atomic Task:

1. Click on the Add Multiple Instance Atomic Task button, , in the Elements panel or right click in an empty part of the canvas and choose **Multiple Atomic Task**.

Go back to the "My Career" Net. We are going to replace our existing "Do Private Study" Atomic Task with a Multiple Instance Atomic task, so click on the "Do Private Study" Atomic Task and delete it. We will add in the new Multiple Instance Atomic task next.

2. Place your Multiple Instance Atomic Task in your Net and set the name of this task by right clicking on the task and choosing **Select Task Decomposition**.

Give this task the same decomposition as before by selecting "Do Private Study" from the drop-down list.

Reconnect the flow relations from "Begin My Career" to "Do Private Study", and from "Do Private Study" to "Get A Job", as per Figure 4.11.

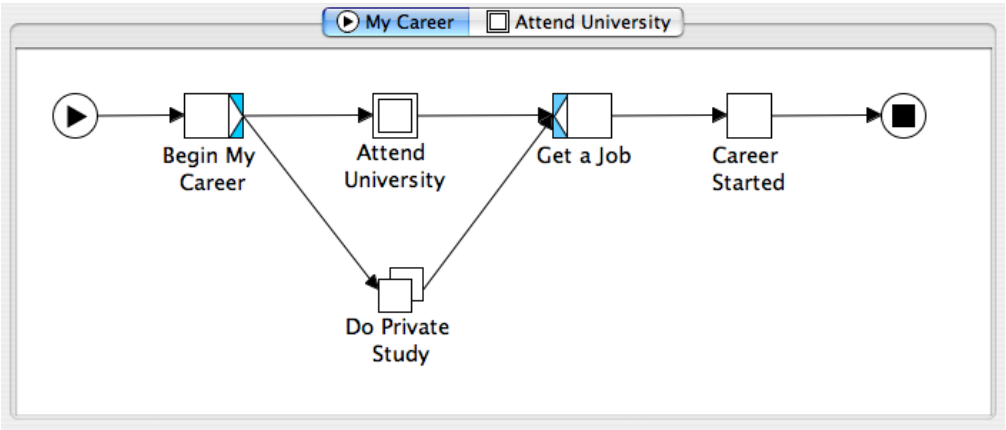


Figure 4.11: Adding a Multiple Atomic Task

3. You will now need to set the parameters of the MI Task, which, being multiple instance, needs a few more values set than a simple atomic task. Right click on the task and choose **Set Instance Detail**. Ensure that you are viewing the "Bounds" tab of the dialog, as per Figure 4.12.

4. Choose the Instance Creation mode. In either mode, the number of task instances created at runtime for the task will be between the values given for "Minimum Instances" and "Maximum Instances". *Static* mode means the number of task instances started cannot vary once the task is activated. *Dynamic* mode means the same number of task instances (as static mode) are started initially, but new instances of the task may be started dynamically at runtime (i.e. after task execution has begun), up to the value entered in "Maximum Instances".

Set the Instance Creation type to "Static".

5. Set the Minimum Instances value. This is the minimum number of instances of this task that will be started when the task is activated.

Set the Minimum Instances to 5.

6. Set the Maximum Instances value. This is the maximum number of instances of this task that can be created from this task.

Set the Maximum Instances to 100.

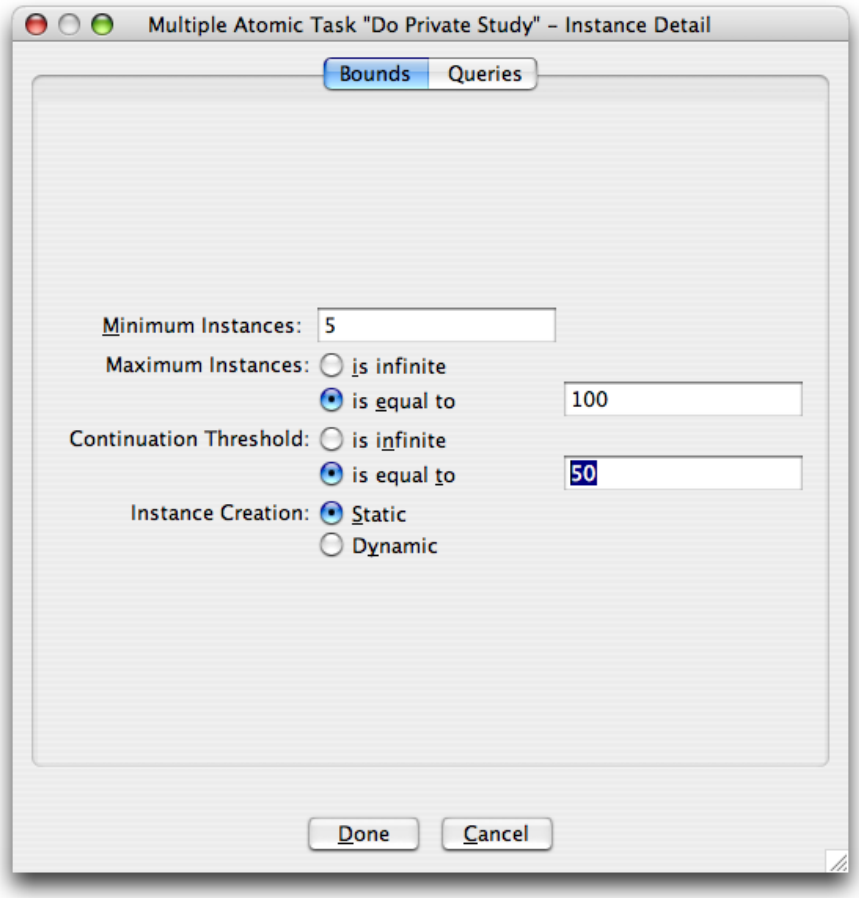


Figure 4.12: Instance Bounds on Multiple Instance Tasks

7. Set the Continuation Threshold value. The moment all task instances created have completed, or if the number of instances created exceeds the Continuation Threshold, the number specified for the Continuation Threshold have completed, the multiple instance task itself will be considered complete, and will trigger relevant outgoing flow relations from this task.

   Set the Continuation Threshold to 50.

8. Click **Done**.

With the values set in the scenario, we have specified that the "Do Private Study" task can have a maximum of 100 instances created, a minimum of five instances will be created, and once 50 instances (or all those started if less than 50) have completed, the outgoing flow relation to ''Get A Job" will trigger.

We will revisit the setting of parameters for multiple instance tasks, in particular the details of the "Queries" tab of the Multiple Instance Detail dialog, in Section 4.5.9, after the basics of queries have been introduced.

4.3.4 Multiple Instance Composite Tasks

Multiple Instance Composite Tasks allow you to run multiple instances of the sub-net represented by a multiple composite task, concurrently.

To create a Multiple Composite Task:

1. Click on the Add Multiple Composite Task button, , in the Elements panel or right click in an empty part of the canvas and choose **Multiple Composite Task**.

Go to the "My Career" Net. We are going to replace our existing "Do Private Study" Multiple Instance Task, with a Multiple Composite task, so click on the "Do Private Study" Task and delete it. We will add in the new Multiple Composite task next.

2. Place your Multiple Composite Task in your Net.

Reconnect the Flow Relations from "Begin My Career" to the new Multiple Composite Task, and from the new Multiple Composite Task to "Get a Job".

3. Next, create a new Net by clicking on the New Net button, , on the Menu Toolbar, or click on **Net** in the Menu and choose **Create Net**.
4. Give the new Net a name by clicking on the **Net** Menu and choosing **Update Net Detail**.

We are going to call this new Net "Study Privately".

5. Return to your original Net and right click on your Multiple Composite Task and choose **Unfold to Net**. You will then be given a drop-down list with all the Nets Available – choose the Net for this task to initiate and then click **Done**.

Choose "Study Privately".

The previous 3 steps can be concatenated into a single step by placing the Multiple Instance Task on the net, then right-clicking on it and selecting ***Unfold to Net****, then clicking the* Create *button on the dialog that appears.*

6. You will now need to set the parameters of the Multiple Composite Task, in the same manner as those set previously for the Multiple Atomic Task. Right click on the task and choose **Set Instance Detail**.

Set the Minimum Instances to 5, the Maximum Instances to 100, the Continuation Threshold to 50, and the Instance Creation type to "Static".

7. Click **Done**.
8. You can now complete your new "Study Privately" Net represented by your Composite Task.

Create the following Atomic Tasks in order and then link them with Flow Relations as per Figure 4.13:

- Read a Book
- Feel Smarter

4.3.5 Conditions

Conditions represent states of the workflow and are located between two tasks. To create a Condition:

1. Click on the Add a Condition button, , in the Elements panel or right click on an empty part of the canvas and choose **Condition**.

Go to the "Study Privately" Net. We are going to place a loop Condition after the Read a Book atomic task, to determine whether we gained any knowledge from the book. We will add the new Condition next.

2. Place your Condition in your Net and set the name by right clicking on the Condition and choosing **Set Label**.

   Call this Condition "Knowledge Gained?".

3. Now link to the Condition to the tasks of the net using flow relations.

   Select the flow relation between the Read a Book atomic task and the Feel Smarter Atomic Task and delete it.
   Create a flow relation from the "Read A Book" task to the "Knowledge Gained?" condition.

4. Create a flow relation from your condition to a task.

   Set the flow relation from the "Knowledge Gained?" condition to "Feel Smarter" atomic task.

5. Create another flow relation from your condition to another task to signify the two possible flows from the condition.

   Before we create our second flow relation from our condition, first create another atomic task and call it "Look for An Easier Book".

   Add an XOR join decoration to the "Read a Book" task, with the orientation being West.

   Finally create the Flow Relation from the "Knowledge Gained?" condition back to the XOR join of the "Read A Book" atomic task, as per Figure 4.13.

6. Validate your specification.

   Validation should fail and report errors as per Figure 4.13. The problem here is that the "Study Privately" multiple instance composite task needs to have more information specified for it to be valid.

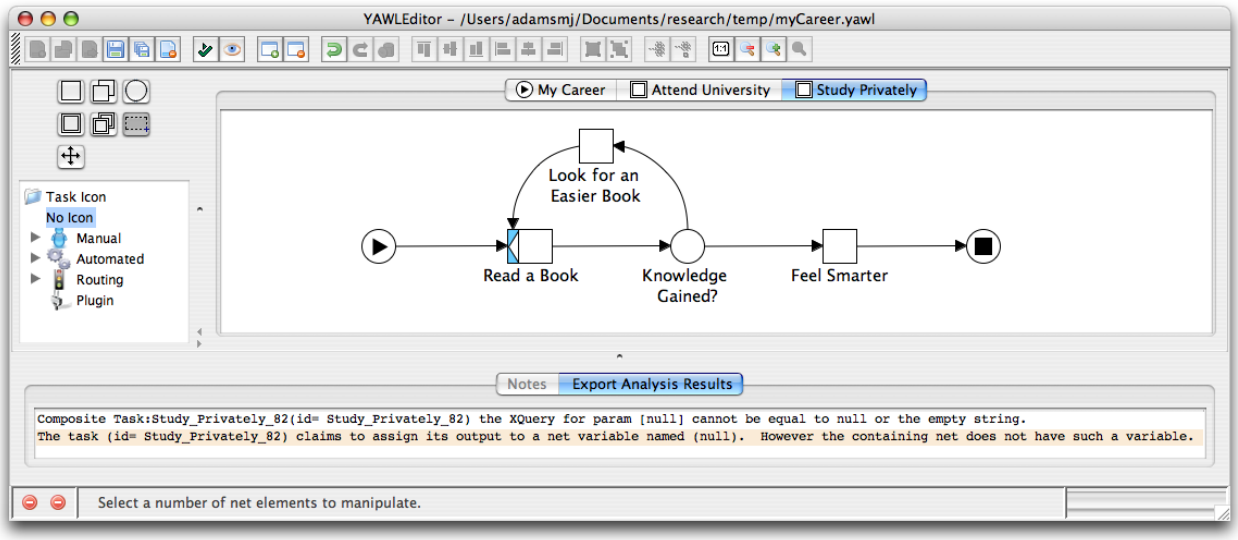

YAWLEditor – /Users/adamsmj/Documents/research/temp/myCareer.yawl
My Career
Attend University
Study Privately
Task Icon
No Icon
Manual
Automated
Routing
Plugin
Look for an Easier Book
Read a Book
Knowledge Gained?
Feel Smarter
Notes
Export Analysis Results
Composite Task:Study_Privately_82(id= Study_Privately_82) the XQuery for param [null] cannot be equal to null or the empty string.
The task (id= Study_Privately_82) claims to assign its output to a net variable named (null). However the containing net does not have such a variable.
Select a number of net elements to manipulate.

Figure 4.13: Validation with unfinished Multiple-Instance Tasks

For setting data detail of multiple-instance tasks, please see Section 4.5.9.

7. Remove the "Study Privately" multiple-instance composite task and replace it with an atomic composite task using the same decomposition, and re-drawing flows from "Begin My Career" and to "Get A Job" tasks. Your updated net should look like Figure 4.14, and should validate successfully.

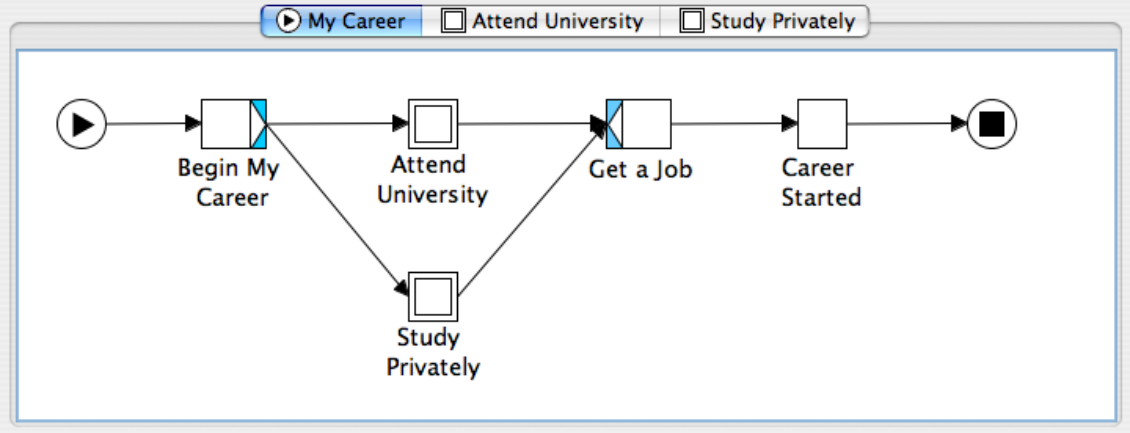


Figure 4.14: Making the "Study Privately" task an atomic composite

The *Knowledge Gained?* condition in Figure 4.13 shows an example of a *Deferred Choice* construct. When the condition is reached during execution of the process, both of its outgoing flows are activated (note that a condition may have any number of outgoing flows). This results in both the "Look for an Easier Book" and "Feel Smarter" tasks appearing in the user's worklist, allowing the user to make a (deferred) choice between the two. As soon as the user chooses the appropriate task for execution, the other task is immediately withdrawn and is removed from the worklist.

4.3.6 Changing the Starting Net

At any stage you can change the Starting Net of the specification. To change the Starting Net:

1. Select **Net** from the Menu.
2. Choose **Set Starting Net** (Figure 4.15).
3. From the Choose Starting Net window, click on the drop-down list and select a new starting Net.
4. Click **Done**.

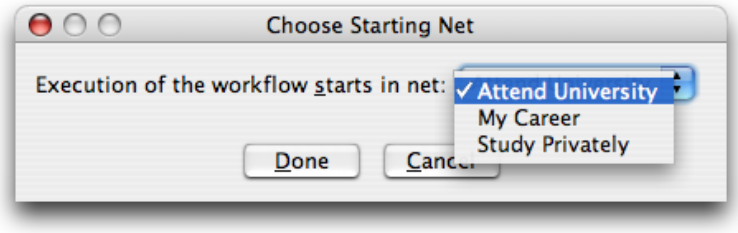


Figure 4.15: Changing the Starting Net

Note that the starting net has an input condition symbol, , in its title tab, and in the View menu list. All sub-nets have a composite task symbol, , in their title tab, and in the View menu list.

4.4 Changing the Appearance of Your Specification

4.4.1 Changing Flow Relations

Bends and Curves

You can control and improve the look of the flows between tasks by adding "bends" in them.

Go to the "Study Privately" Net.

Right click on the position in the flow where you want to add a bend, which will be denoted by a small blue square, , in the Flow. A popup menu will appear, allowing you to add and remove bends, as well as change the line style of the flow.

Create a bend somewhere towards the middle of the flow going from the "Knowledge Gained?" condition to the "Look for an Easier Book" atomic task. Then left click on the bend marker created and drag it out to a more desirable location. You can add as many bends to a flow as you like.

Repeat the process for the flow between "Look For an Easier Book" and "Read A Book" tasks (see Figure 4.16).

Relocation

You can reconnect flow relations to other elements of a net, or different points on the same element by selecting the flow, and dragging one of its connecting ends from one net element to another. If a connection is possible at some other element, connection points will become visible as described earlier. Release the mouse button to attach the flow to its new home.

Take the current flow relation, and move it from the top of the task to its side, as depicted in Figure 4.16.

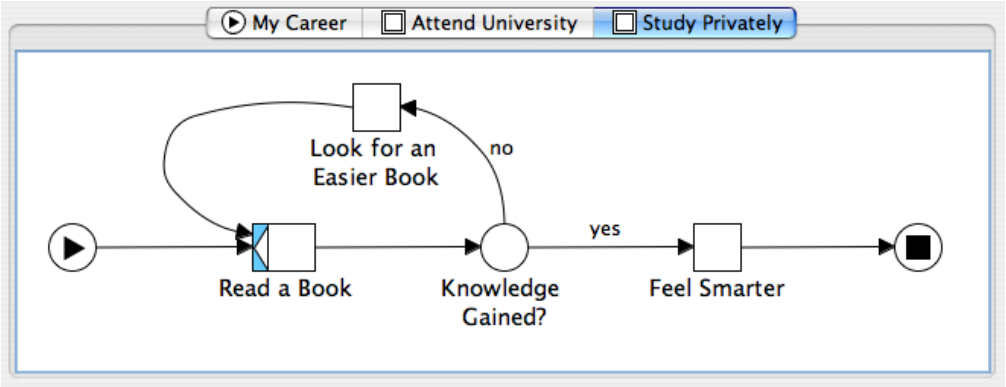


Figure 4.16: Adding bends to a Flow Relation

Adding Labels

It is also possible to add labels to flows. To do so, double click on a flow. A small text input box will appear over the flow. Type your desired text, and commit the flow label by pressing the ENTER key. You may then drag that flow label around to position it as desired.

Take the two flow relations that have recently had bends added to them. Attach the label *yes* to the flow relation going from the "Knowledge Gained?" condition to the "Feel Smarter" atomic task. Attach the label *no* to the flow relation going from the "Knowledge Gained?" condition to the "Look for an Easier Book" atomic task. Drag the labels about to a desired position, much like what's been done in Figure 4.16.

Note that Figure 4.17 shows flows using two different line styles. The flow running from "Look for an Easier Book" has been given the "spline" line style in this figure, while the remaining flows are all "orthogonal", resulting in sharp edged bends on flows, such as the one running from the "Knowledge Gained?" condition to the "Look for an Easier Book" task.

Setting Colours

For nets, the default background colour can be set (i.e. applied to all nets) by choosing *Default Net Background Colour...* from the *View* menu. To set the background colour of individual nets, choose *Net Background Colour...* from the *Net* menu.

For tasks and conditions, the default fill colour (i.e. for all newly added tasks and conditions) can be set by choosing *Default Element Fill Colour...* from the *View* menu. For individual tasks and conditions, right click on it then choose *Set Fill Colour...* from the popup menu. Several selected tasks and/or conditions can have their fill colour set at the same time by choosing *Set Selected Fill Colour...* from the *Elements* menu.

4.4.2 Editing Objects

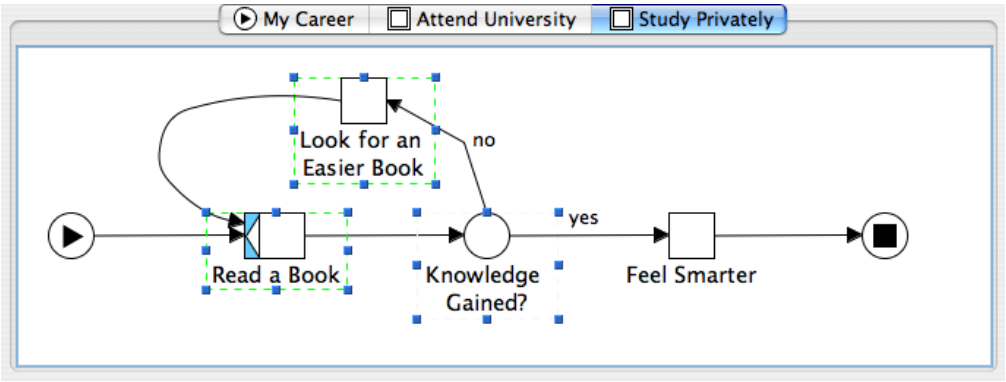


Figure 4.17: Changing the Size of Multiple Objects

You can edit more than one object at a time by using the Marquee Selection tool. See Figure 4.17.

1. Select the Marquee Selection tool, , from the Elements panel.
2. Click on the first object that you want to edit, then hold down the shift key and then click on the other objects that you want to edit.
3. Alternately, click and drag the Marquee tool to include multiple items in the drag rectangle.

4. Now choose the **Edit** option from the Menu or continue holding down the shift key and right click on the mouse button. Below are the edit options:
   - Cut, Copy, Delete;
   - Align;
   - Size Increase / Decrease to change the appearance of the objects. This can also be done using the CTRL key plus Up or Down arrow on your keyboard.

Note also, that whenever you have selected a number of net elements, pressing one of the arrow keys will move the selected elements in the direction of the arrow key, and pressing the CTRL key plus the A key will select all the elements in the currently selected net.

4.4.3 Changing Font Size

You can change the size of the font used to label tasks and conditions.

1. Change the font size by clicking on the **View** Menu and choosing the **Label Font Size...** option.
2. Change the font size to that desired. The specified font size applies to all text drawn on the canvas.

4.4.4 Changing Task Icons

You can add or change the icon that is shown on atomic tasks.

1. Select any single atomic task in your workflow. The palette will expand to include a task icon tree, depicted in Figure 4.13, where you can an icon from the tree to the task. You are free to assign any icon. Icons have no runtime effect on the engine, and are provided simply to make specifications more easily understood by people looking at the specification in the editor.

4.4.5 Using Custom Icons

Workflow designers can plug in and use their own icons for specification design. Icons must be of the PNG file format, and be a maximum of 24 $\times$ 24 pixels to render properly within editor task boundaries.

The editor will load user-supplied task icons from the location specified for them in the *Settings...External File Paths* dialog (see Figure **??**); if never specified, the location defaults to the directory:

```
<editor_installation_path>/YAWLEditorPlugins/TaskIcons
```

and if found adds them into the plugin branch of the task icon tree widget of the editor's palette. Sub-directories are supported, and will form new sub-trees of the same name when the plugin sub-tree is being created. If an icon cannot be found that was previously used for a specification, a special "broken" icon will render in its place, as depicted in Figure 4.18.

Figure 4.18: A task specifying an icon that the editor cannot locate

4.5 Additional Specification Features

4.5.1 Cancellation Sets

Cancellation Sets allow you to nominate any number of tasks, conditions and/or flow relations (which, when they join two tasks directly, contain an *implicit* condition that is not visible on the net) for cancellation, upon the completion of a specified task. That is, once a specified task has completed execution in a workflow instance, all other net elements within that task's nominated cancellation set (if any) are deactivated.

To create a Cancellation Set for a task:

1. First select the task that will initiate the Cancellation Set.
2. Right-click on the task, then choose **View Cancellation Set** from the context menu. The task will fill with a grey colour to indicate that this is the task that 'owns' the cancellation set currently on view.

   Create the "Purchase Book" specification as shown in Figure 4.19. In this example, we are going to purchase a book by placing an order with three different sellers; as soon as the first seller fills the order, we want to cancel the other two orders. To achieve this, we create a cancellation set for each "Order" task that includes the other two "Order" tasks. We will step through creating a cancellation set for the "Order from Amazon" task – the other two are created in a similar manner.

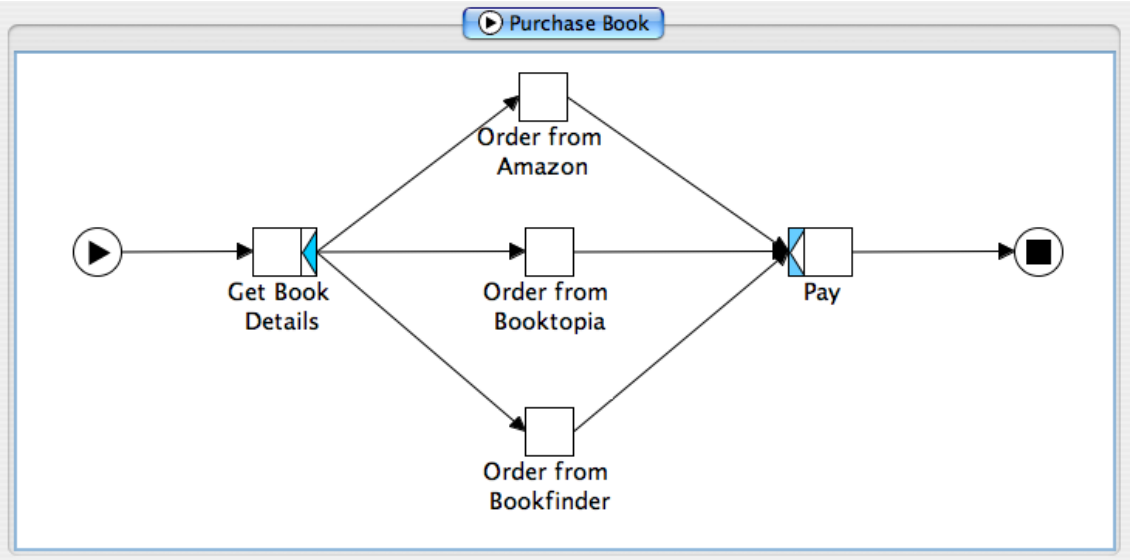


Figure 4.19: The Purchase Book specification

   Right-click on "Order from Amazon" and choose **View Cancellation Set**.

3. Next, choose a task, condition or flow (and thus an implicit condition) to add to the Cancellation Set. Hold down the shift key to select more than one object for cancellation.

   Select the "Order from Booktopia" and "Order from Bookfinder" tasks, and the flow relation preceding each of them.

4. Click on the Add Selected Items to Visible Cancellation Set button, , on the Menu Toolbar. Items will be given a red border to indicate they belong to the cancellation set of the grey-filled task (see

Figure 4.20).

Add the selected tasks and flow relations to the cancellation set.

5. Once you have established the cancellation set, you can right-click on the cancellable task and reselect **View Cancellation Set** to toggle off the cancellation set view.

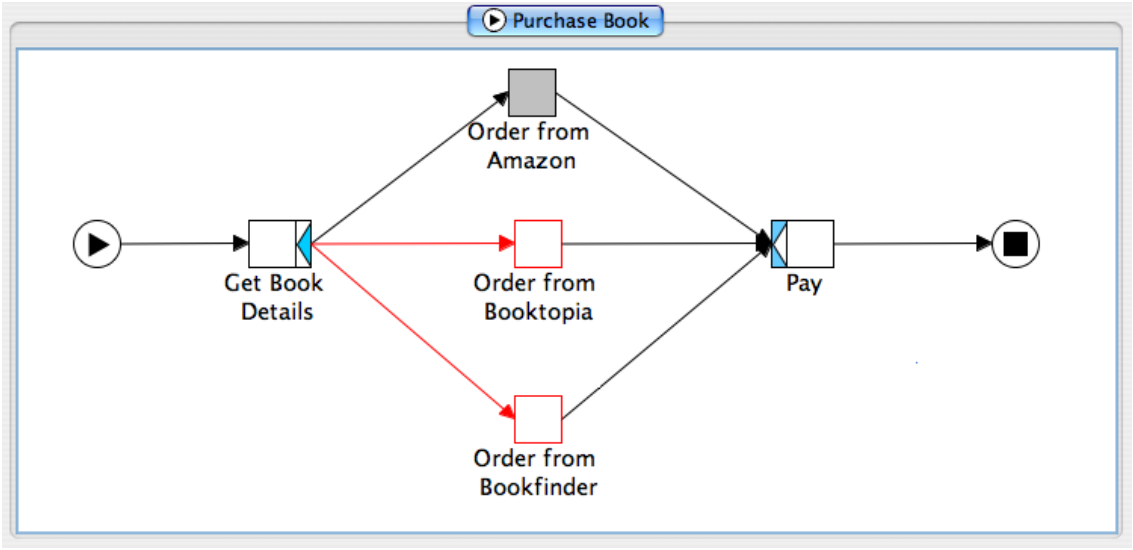


Figure 4.20: A Cancellation Set specified for the 'Order from Amazon' task

Notes about Cancellation Sets:

- In the example in Figure 4.20, notice that there is an AND-split decorating the "Get Book Details" task, but the "Pay" task has an XOR-join. This is because we know that when one of the "Order" tasks completes, the other two will be cancelled, so only one incoming flow to the "Pay" task will activate. Since we want the process to complete, we must add the join type that will activate the task when a single incoming flow activates: the XOR-join. If an AND-join had been used here, it would wait until all three incoming flows were activated, which in this case is never going to happen, and would result in the *deadlock* of the workflow instance. However, without the careful setting of cancellation sets for all three intermediate tasks, the net would represent an example of an *unsound* net, which basically means the net may complete while there were still active tasks within it. Great care needs to be taken when mixing split and join types, and when defining cancellation sets, so that the execution of the net behaves precisely as intended.
- A Cancellation Set that has been created will remain in the specification, regardless of whether you have the **View Cancellation Set** option ticked.
- You can create multiple Cancellation Sets in your workflow, by selecting another task and choosing the **View Cancellation Set** option. Only one cancellation set may be viewed at any one time.
- All flows leading to or from (explicit) conditions are not valid cancellation set members. Neither are the Input and Output conditions. The editor will ignore them if you select them for inclusion in a task's cancellation set.
- A task may be included as a member of its own cancellation set.
- The reason for including preceding flows of a task in a cancellation set is this: If a flow relation connects two tasks directly, then it is said to contain an *implicit* condition. If there is a condition object in the

model between two tasks, so that the connection is task - flow - condition - flow - task (for example, the "Knowledge Gained?" condition in Figure 4.16), it is said to be an *explicit* condition. In either case, when a task completes, it passes 'control' to the condition preceding the next task in the flow. When the next task is started, it takes 'control' from its preceding condition (whether implicit or explicit). If there is a chance that the tasks in a cancellation set may not have started when the owner task of the set completes, then cancelling those tasks will have no effect – it is their preceding conditions that have 'control' and so they are the elements that must be cancelled. By including both tasks and their preceding conditions, we are ensuring that the desired cancellation will occur, regardless of whether the tasks in the set are currently executing or not.

To remove an element from a task's Cancellation Set:

1. First, make sure you have the **View Cancellation Set** option ticked for the task. If it isn't ticked, select the task that has the Cancellation Set, right-click, then choose **View Cancellation Set**.
2. Select the element for removal.
3. Click on the Remove Selected Items from Visible Cancellation Set button, , on the Menu Toolbar.

4.5.2 Data Type Definitions

YAWL uses *XML Schema* to define data documents that are passed from net to task and back during the life of a workflow instance. There are over 40 simple XML Schema data types (string, integer, boolean, etc.), all of which are supported by YAWL.

Figure 4.21: The data type definition dialog toolbar

User-defined data types are also supported, by allowing for the definition of XML Schema complex types, which are added to a specification and then may be used to define variables based on those types. To define a new complex type for a specification:

1. Select **Update Data Type Definitions** from the **Specification** Menu.
2. Enter your XML Schema Data Type Definition into the dialog box. (See Figure 4.22).
3. If the definition text is green, your new data type is a valid definition and may be used for defining Net or Task variables in your specification. If the text is red, there is something wrong with your data type definition, and the data type will not be available. When the text is red, the split-pane will reveal a table listing parse errors that were collected when determining the validity of the text supplied. An example of this is shown in Figure 4.23.

Open the Data Type Definitions dialog and type in the XML text that appears in Figure 4.22.

The Data Type Definition dialog has its own toolbar (Figure 4.21). From left to right, the buttons are:

- Cut, Copy, Paste text;
- Undo, Redo changes;
- Toggle line numbers on and off;
- Format text (correct indentation etc.);

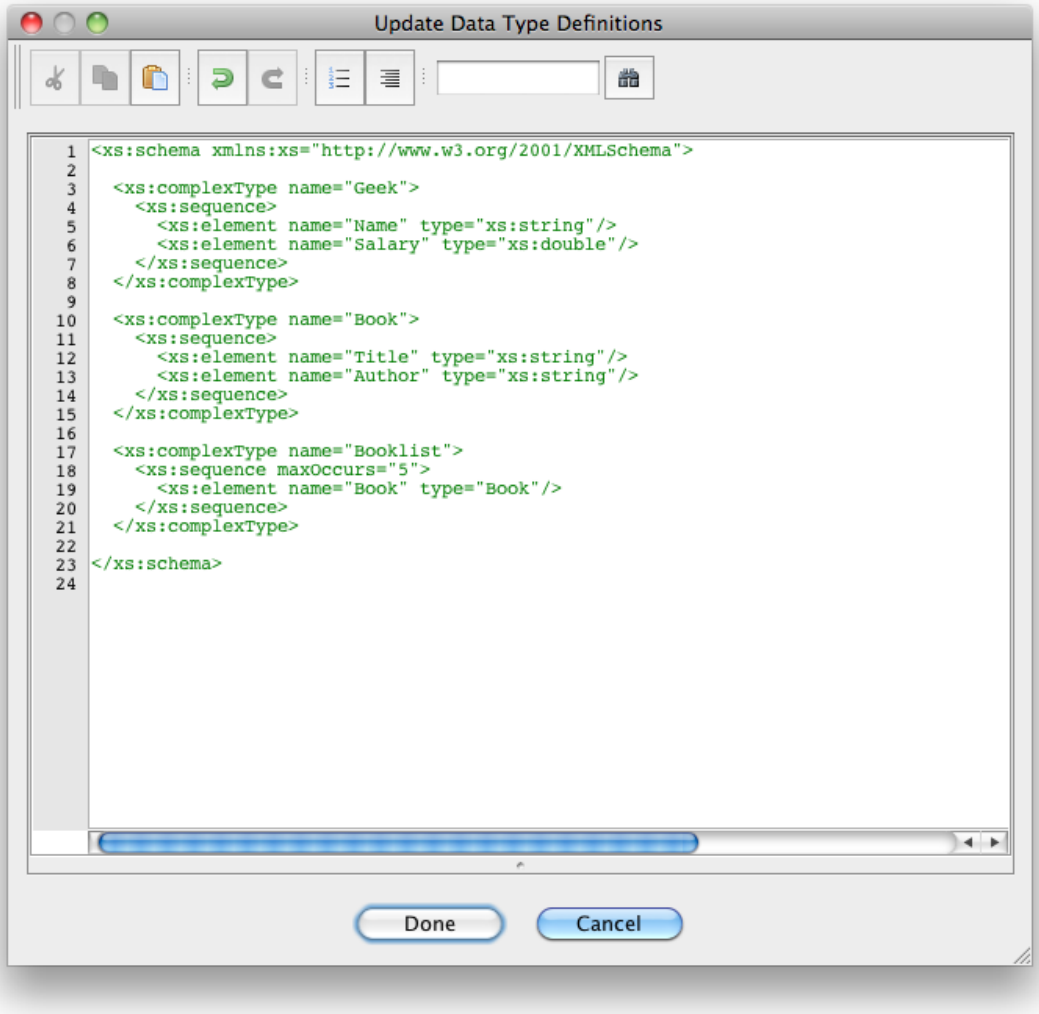


Figure 4.22: Adding the "Geek" complex data type

- Search for text.

The above example creates a complex data type called "Geek" that has two separate sub-components, "Name" and "Salary" of type "string" and "double" respectively. Types called 'Book' and 'Booklist' are created in the same way. As depicted in Figure 4.24, the new data type "Geek" is available to choose from the list of available types when creating a task or net variable. Variables with a usage of "Local" can have initial values specified for them, as depicted in the same figure. As with the data type definition dialog, parse errors will be listed when the initial value text is red.

4.5.3 Net Decomposition Detail / Net Variables

You can add variables to a net to store information relating to that net that tasks within the net may need to read or update.

To add a variable to a Net:

1. Choose **Update Net Detail** from the **Net** Menu.

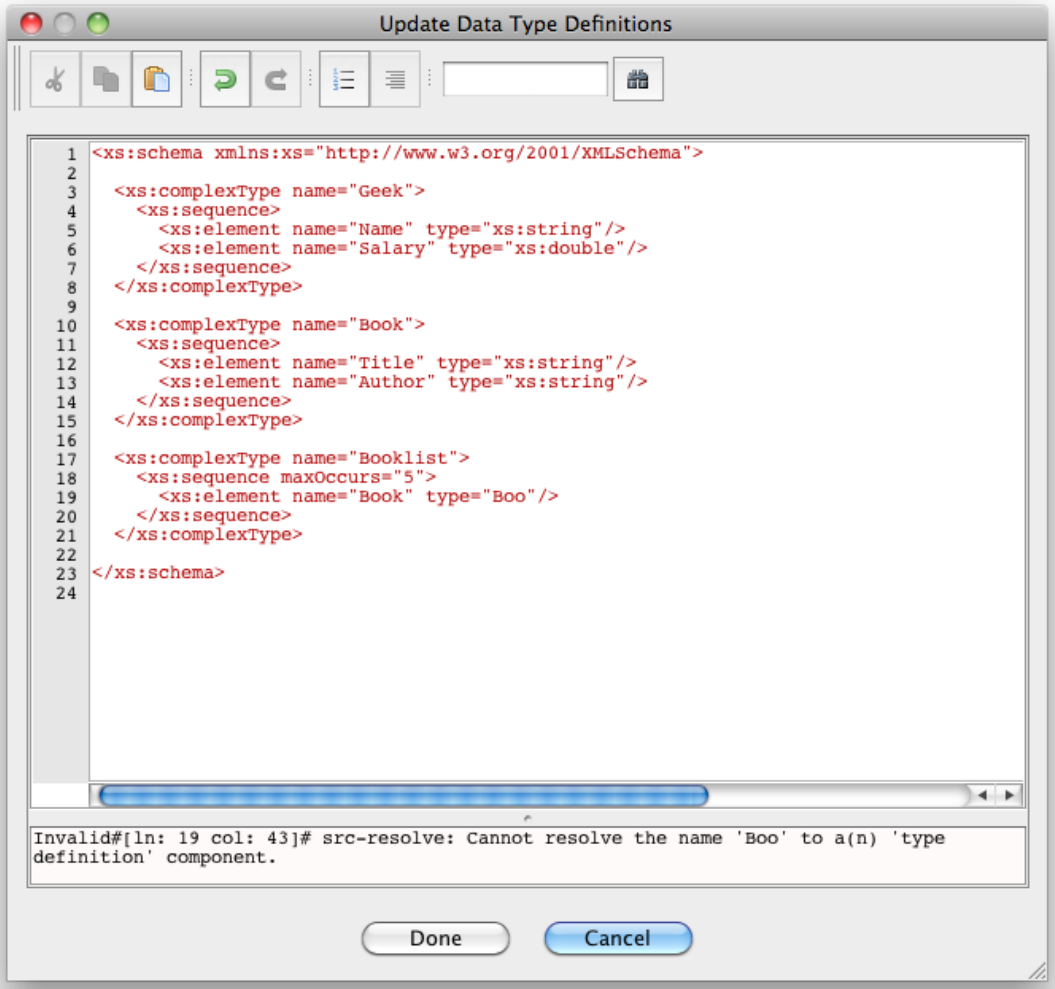


Figure 4.23: When the data type definition is invalid

We will be setting up Net variables in the "Attend University" net. Go to the "Attend University Net" and choose **Update Net Detail** from the **Net** Menu.

2. An Update Net Decomposition dialog box will appear (see Figure 4.25). Click on the **Create** button. This will show an Update Net Variable dialog box (see Figure 4.26).

3. Enter the Name of your variable, choose the Type and intended Usage of the variable from those listed, then click **Done**, then **Done** again to close the Net Decomposition dialog.

Enter "StudentNumber" for the name of the variable, leave the type as "string", and set the Usage type to "Local". Leave the initial value blank. Click **Done** (see Figure 4.26). Create another Net Variable with the name "SubjectCode" and Type "string". Leave the Initial Value blank and set the Usage to "Local" (usage types will be explained a little later). Click **Done**.

4. The Net Variables should now appear in the Update Net Decomposition of Net "Attend University" dialog box (Figure 4.27).

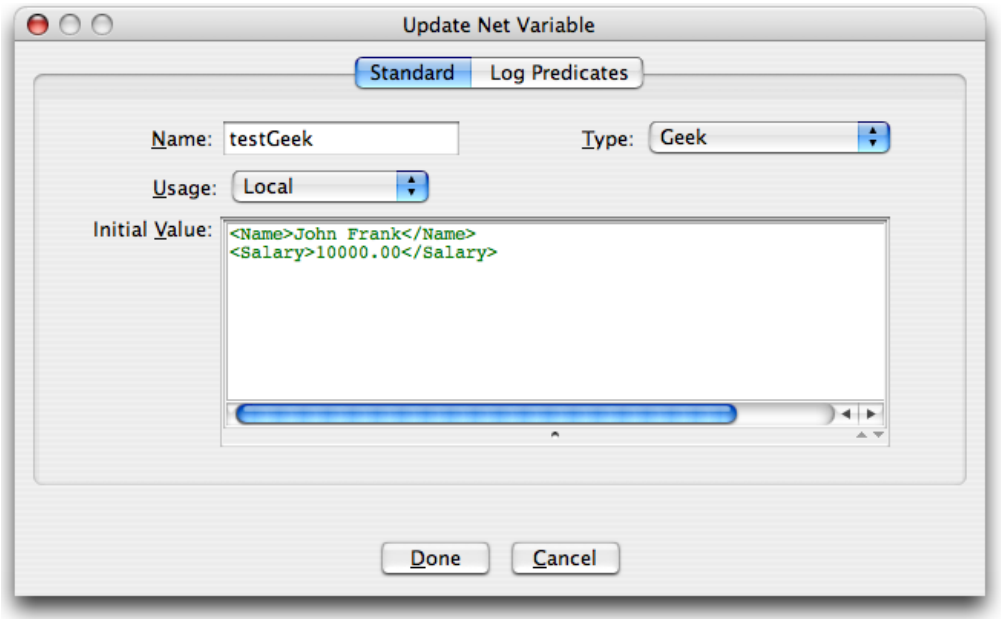


Figure 4.24: A "Geek" net variable with a valid initial value

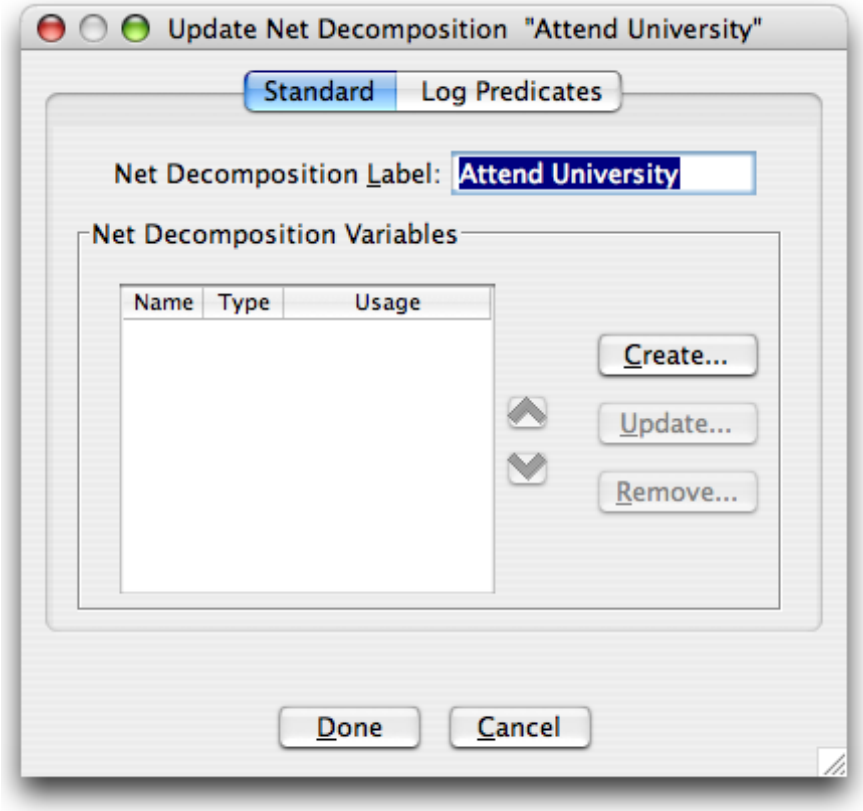


Figure 4.25: Updating "Attend University" Net Variables

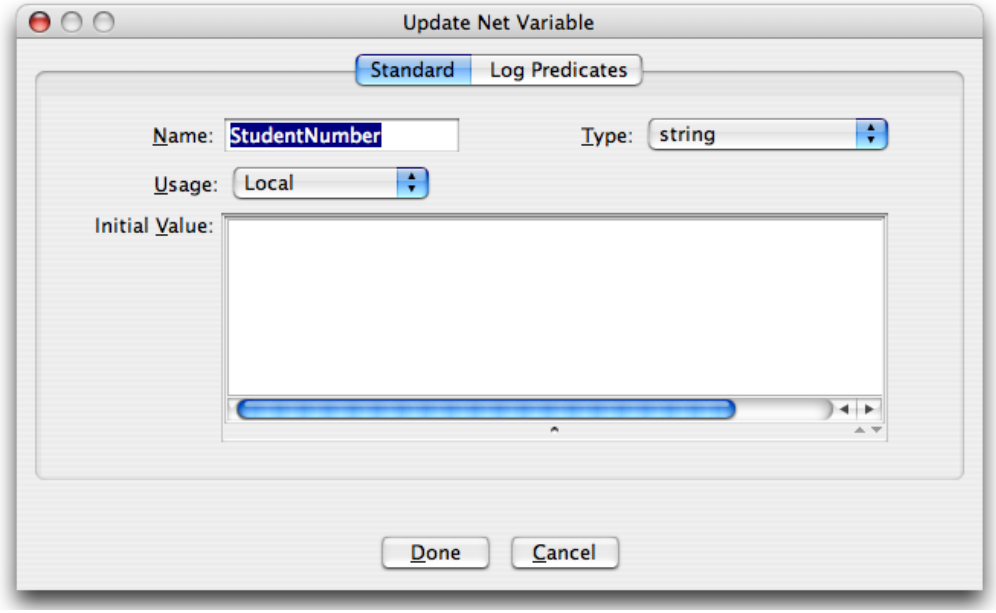


Figure 4.26: The Net Variable "Student Number"

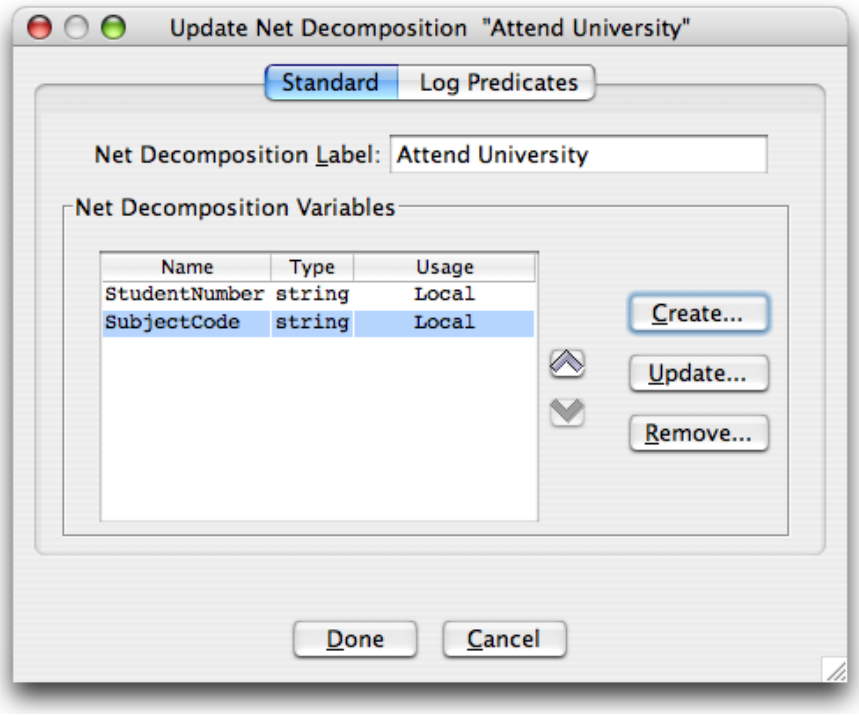


Figure 4.27: Updated "Attend University" Net Variables

4.5.4 Task Decomposition

By choosing the **Select Task Decomposition...** option when you right click on a task, you have the ability to identify which decomposition is attached to the task. A decomposition describes the variables 'handled' by the task, and the YAWL Service that will be responsible for performing the work the task represents at runtime.

Like nets, tasks have decompositions where you can specify variables and a label to associate with the task. Unlike nets, which cannot share net decompositions, there is a 1:N relationship between task decompositions (scoped to the entire specification) and their tasks (scoped to nets), meaning that a number of tasks within a specification may share the same decomposition.

Besides variables and a label, task decompositions also allow the workflow designer to identify which web service the decomposition should invoke in a running workflow engine, and whether the decomposition will create manual (i.e. human-actioned) or automated (non-human-actioned) tasks. When two tasks share the same decomposition, we are saying that the same activity is required in two different places in the workflow (the two tasks may be named the same or differently, but they will share the same underlying definition of work).

From the Select Task Decomposition dialog, you can use the drop-down list to select an existing decomposition, or alternately you can click the **Create...** button to generate a new one that will become the task's decomposition (Figure 4.28).

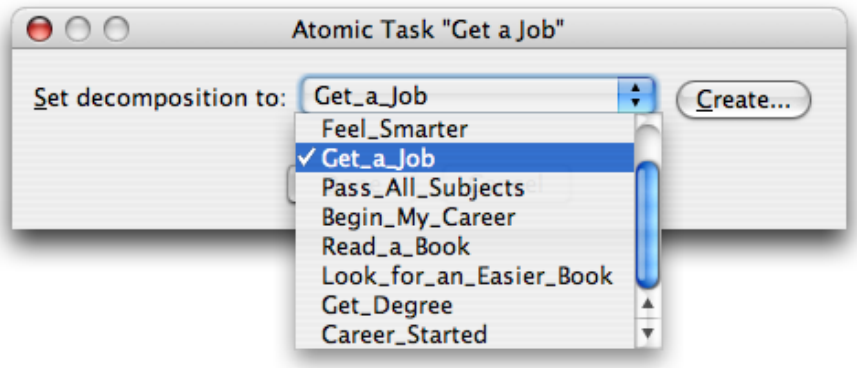


Figure 4.28: Select Task Decomposition (example 'Get a Job' task)

4.5.5 Task Decomposition Detail / Task Variables

You can add variables to a task to store specific information relating to that task, in a similar way to adding variables to a net. Task variables have several uses. One use is for transferring information between workflow users and the workflow engine. A second use is for passing data between web services and/or external code and/or applications that the running workflow engine invokes and the Net the task resides in.

For example, if your task is called 'Purchase a Book', you may want to store the name and/or ISBN of the book being ordered.

4.5.6 Adding a Variable to a Task

1. First select the task that will require the variable.

   We will be setting up variables for the "Enrol" task. Go to the "Attend University" Net and select the "Enrol" task.

2. Right-click on the task and choose **Task Decomposition Detail...**. An Update Task Decomposition dialog box will appear.

   Retrieve the decomposition detail for the "Enrol" task.

3. Click on the **Create...** button. An Update Task Variable dialog box will appear.

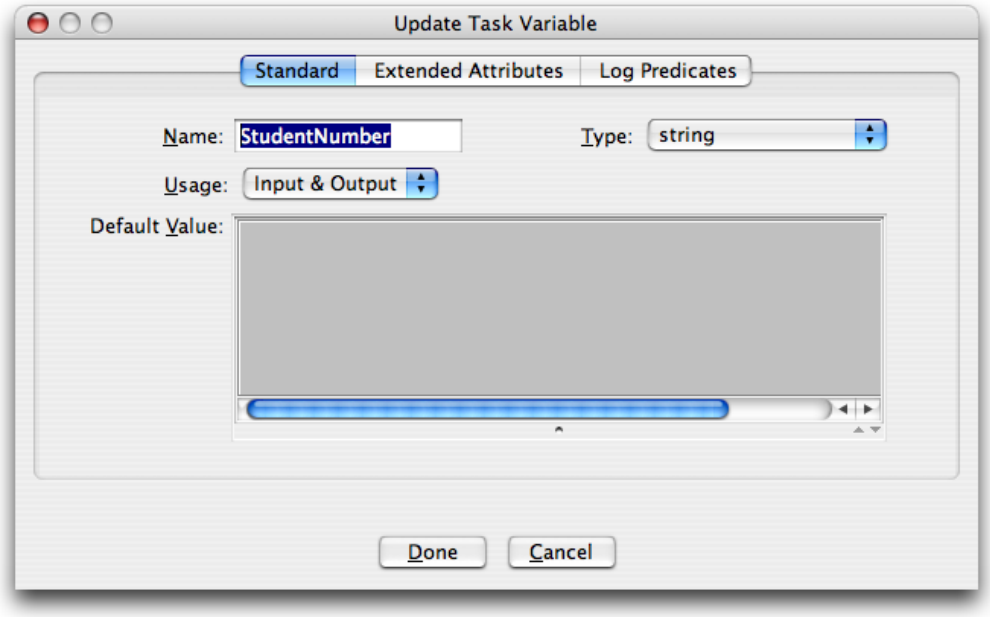


Figure 4.29: Updating the Task Variable

4. Enter the Name of your variable, choose the Type of the variable and its Usage from those listed, click **Done**, then **Done** again to exit the task decomposition detail dialog.

   Enter "StudentNumber" for the name of the variable, leave the type as **string**, and set the Usage to "Input & Output". (Figure 4.29). Click **Done**. Create another variable for the same task, called "SubjectCode" with type **string** and usage of "Input & Output". Click **Done**.

5. The "Enrol" task now has two variables, "StudentNumber" and "SubjectCode" (Figure 4.30).

4.5.7 Task Parameters

A *parameter* defines how a value is assigned to a variable, and how a value is passed between net-level and task-level variables and vice-versa. Both Input and Output Parameters can be assigned to any tasks (depending on their usage type) to allow the passing of state between nets and their tasks, and between tasks and workflow engine, users and web services. Data may also be assigned to and from net and/or task variables directly from an external data source (more later in this section).

Defining Parameters with XQuery

Parameters may be defined using *XQuery* expressions[2]. Input Parameters use an XQuery expression to specify a value (possibly drawing on a number of static and/or net-level variable values) that can be passed to a single selected task variable. Output parameters use an XQuery expression to specify a value that can be passed to a single selected net variable.

For example, if a task is called 'Lookup Book', then an Input Parameter could pass the name of the book to a task variable, whereas the Output Parameter of that task may produce the corresponding ISBN for that book.

To add an Input Parameter:

[2] An examination of the XQuery language is beyond the scope of this chapter; good XQuery learning resources can be found at www.w3schools.com/xquery/default.asp and www.xquery.com/developers/

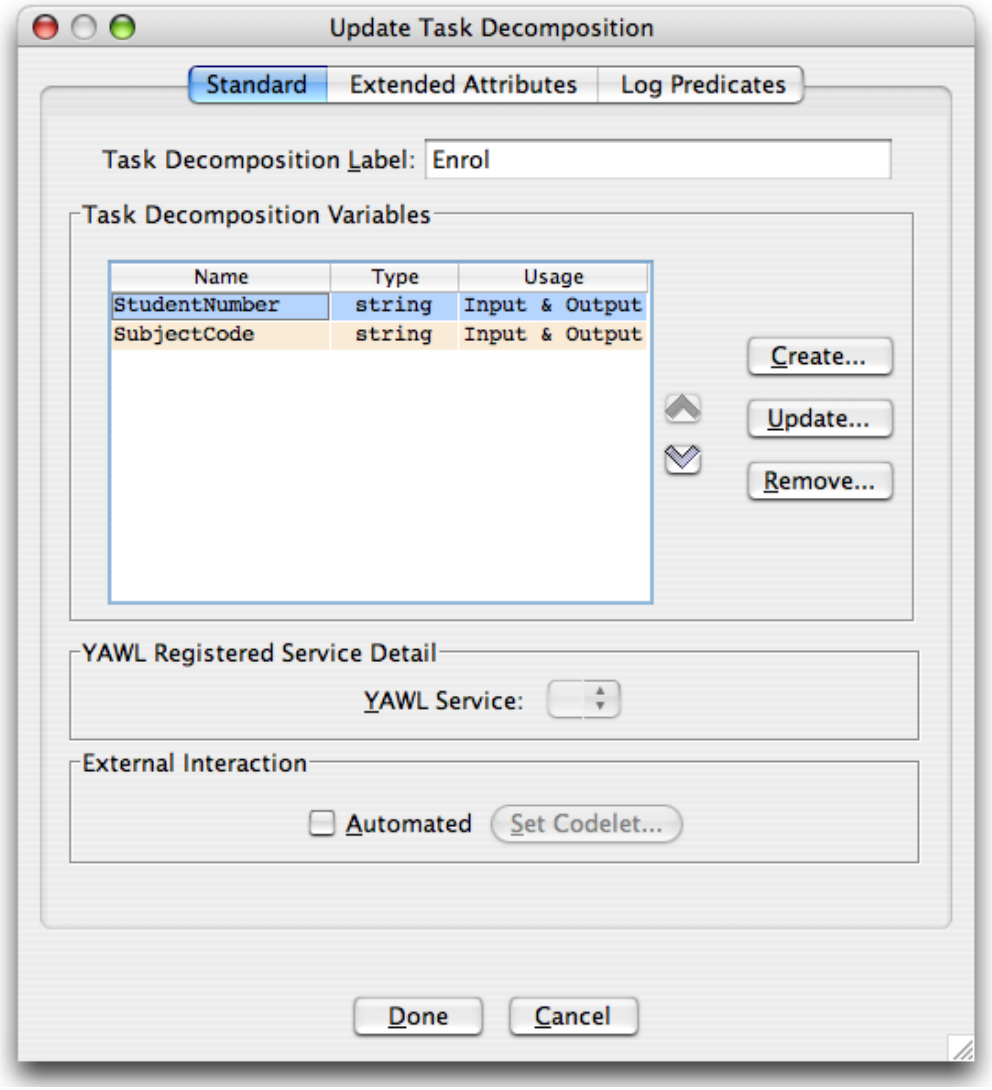


Figure 4.30: The Update Task Decomposition dialog for the Enrol task

1. Select the task to add the parameter to.

We will be setting up Input Parameters for the variables that we created in the Adding / Updating Task Variables section previously. Go to the "Attend University" Net and select the "Enrol" task.

2. Right-click on the task and choose **Update Parameters Mappings...**. An Update Parameter dialog box will appear (Figure 4.31).

Update the Parameters for the "Enrol" task. Notice that the dialog in Figure 4.31 lists both this task's variables, and the variables of its containing net.

3. In the Input Parameters section, click on **Create...**. An Update Task Parameter dialog box will appear. If you have already set up a Task Variable for this task, then the Existing Task Variable option will be activated and there will be a list of task variables to choose from. Choose a variable from the list and click on **Done**, then **Done** again to close the task parameters dialog.
If you haven't set up Task Variables, then click on **Create...** and return to the previous section dealing

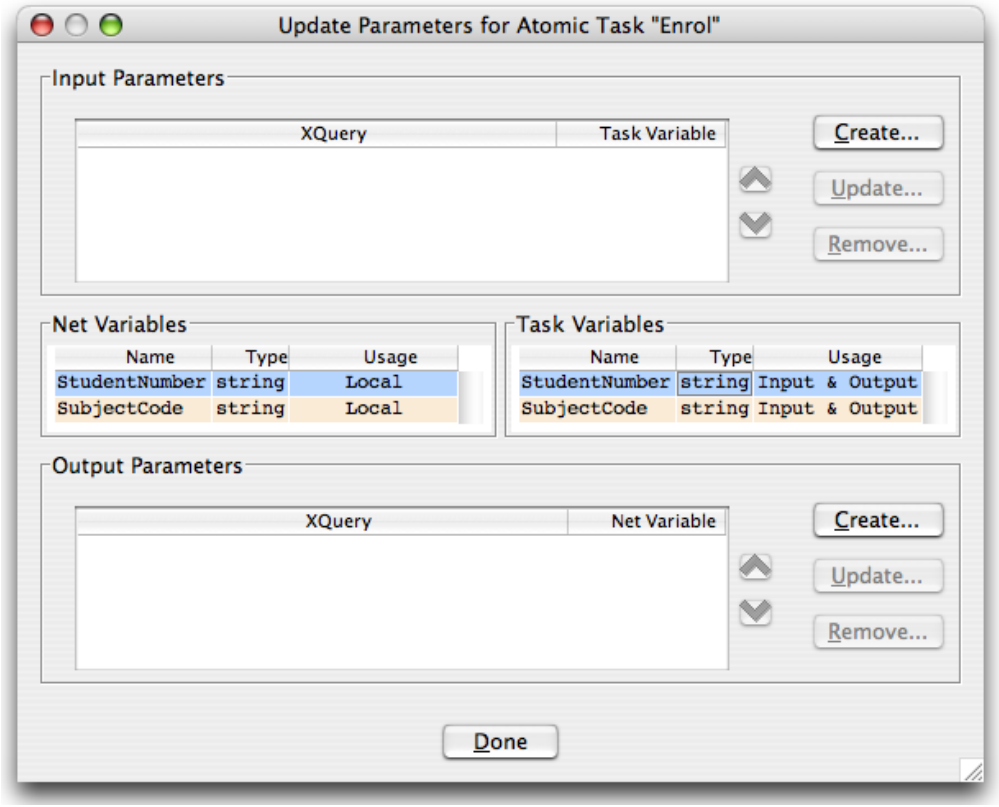


Figure 4.31: Updating Parameters for a Task

with Task Variables (Section 4.5.7).
If you are familiar with XQuery syntax, then you can add an XQuery expression to allow manipulation of the Input Parameters. "Syntactically well formed" XQueries will be green, and badly formed ones will be red. Again, red text will be accompanied by a split-pane table, returning the parse errors that cause the text to be badly formed.
For workflow designer convenience, two XQuery buttons are supplied to automatically generate XQuery expressions from available net variables.
The **add XQuery of element's content** button will return just the content of the XML element for this variable, which is useful for simple value transfer between two variables of the same XML Schema type, and is expected will be the button used in most cases.

The other button, **add XQuery of entire element**, will return the entire XML element of the selected variable, which is useful for times when you want to create a complex type expression from individual variable elements. Experience with XMLSchema and XQuery are necessary to understand the effects this button will have on runtime YAWL engine state.

Select the "StudentNumber" variable from the list of Existing Task Variables. Select the "StudentNumber" net variable, then click **add XQuery of element's content** (Figure 4.32). Click **Done**. Create another Task Parameter and map the net "SubjectCode" to the task variable of the same name using this technique. Click **Done** and **Done** again.

To add an Output Parameter:

1. First select the task to add the parameter to.

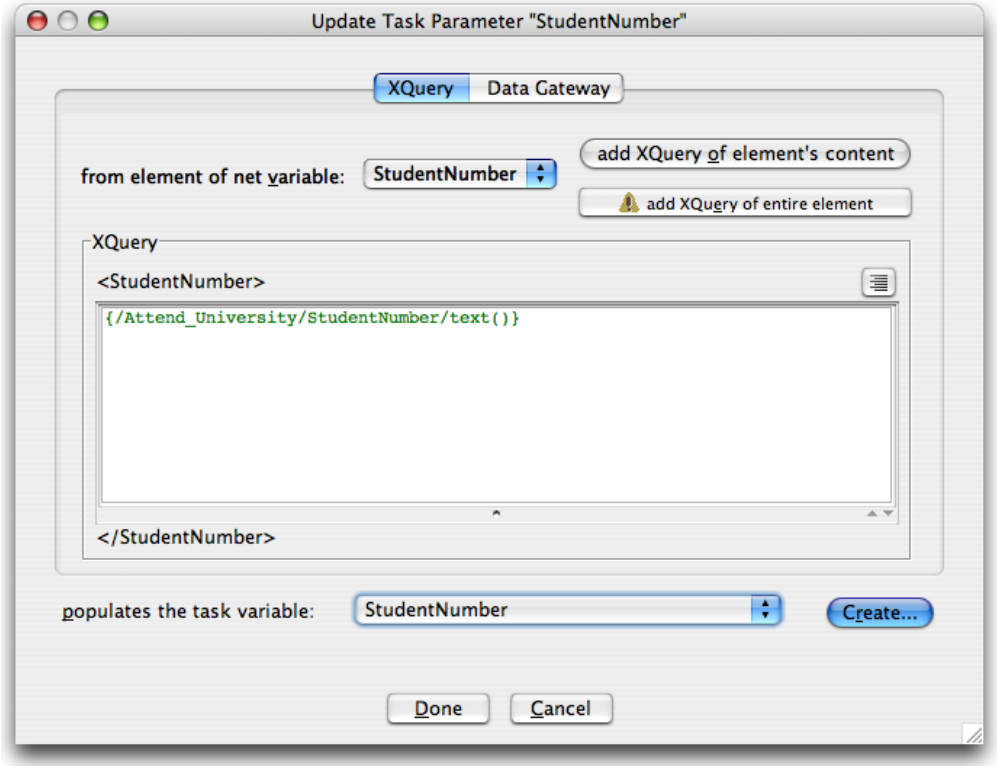


Figure 4.32: Passing a net's StudentNumber value to a Task variable

We will be setting up Output Parameters for the variables that we created in the Adding / Updating Task Variables section. Go to the "Attend University" Net and select the "Enrol" task.

2. Right-click on the task and choose **Update Parameters...**. An Update Parameters dialog box will appear (Figure 4.32).

Update the Parameters for the "Enrol" task.

3. In the Output Parameters section, click on **Create...**. An Update Net Parameter dialog box will appear (similar to Figure 4.32).

4. If you have already set up a Task Variable for this task, then the Existing Task Variable option will be activated and there will be a list of task variables to choose from. Choose a variable from the list and click on **Done**, then **Done** again to close the task parameters dialog. If you haven't set up Net Variables, then click on **Create...** and return to the previous section (Section 4.5.3).

   If you are familiar with XQuery syntax, then you can paste in an XQuery to allow manipulation of the Output Parameters. "Syntactically well formed" XQueries will be green, and badly formed ones will be red. For workflow designer convenience, two XQuery buttons are supplied to generate XQuery expressions from available task variables.

   The **add XQuery of element's content** button will return just the content of the XML element for this variable, which is useful for simple state transfer between two variables of the same XML Schema type, and expected to be the typical button that users will start out with.

The other button, **add XQuery of entire element**, will return the entire XML element of the selected variable, which is useful for times when you want to create a complex type expression from individual variable elements. Experience with XMSchema and XQuery are necessary to understand the effects this button will have on runtime YAWL engine state.

From the list of task variables, select the "SubjectCode" task variable and click **add XQuery of element's content**. From the list of net variables, select the "SubjectCode" variable. Click **Done**. Create another Task Parameter and map the task "StudentNumber" to the net variable of the same name using this technique. Click **Done** and **Done** again.

These Parameters were set up to demonstrate a simple transfer of state from a net to a task and back to the net. Perhaps the task would allow a user to change the values of one of the variables which would eventuate in the net's values changing.

The Update Parameters dialog box should appear as in Figure 4.33.

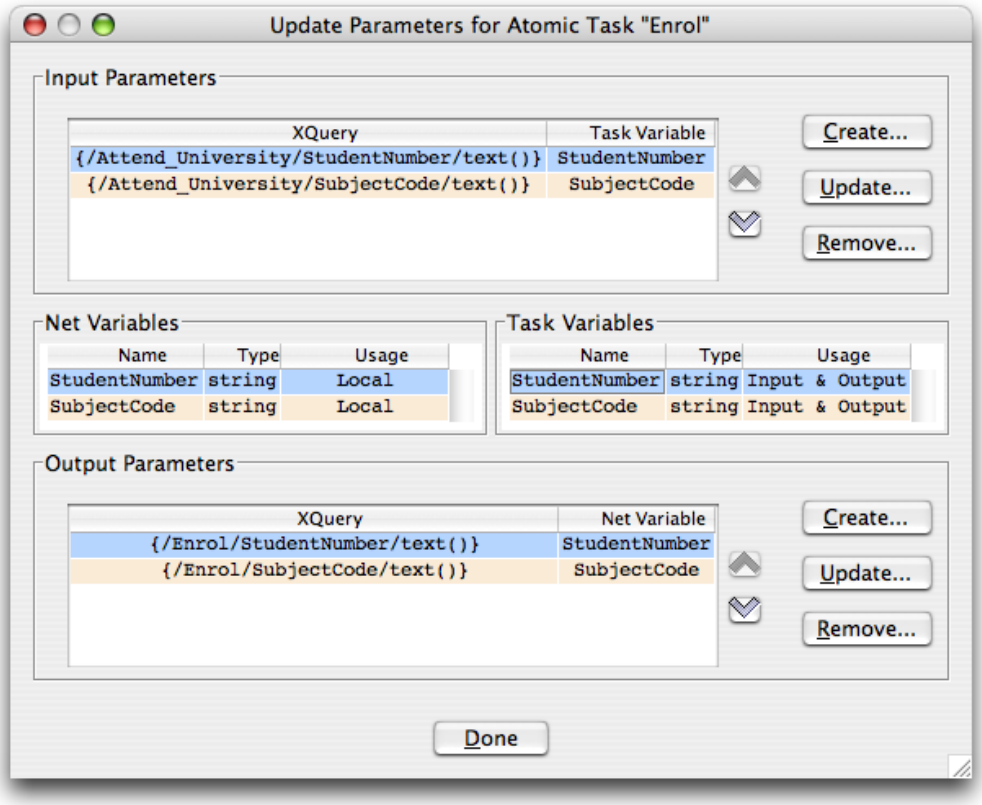


Figure 4.33: Established task parameters with XQuery mappings

Now that we have an understanding of net-level and task-level tasks, and how to create parameters to map values between them, we can revisit the earlier example from Section 4.5.7, where we created two local variables for the sub-net "Attend University". By creating them with *local* usage type, they have local scope and so are actually different variables than those of the same name created in the outer (parent) net "My Career". If you wanted to map the values of those variables from the parent net to the sub-net, then their usage type in the sub-net will need to be changed from *local* to *Input Only* (since they are not to be updated in the sub-net's tasks), the perform the appropriate mapping between the parent net and the

"Attend University" composite task, following the method described above.

Defining Parameters using External Data Sources

As an alternative to mapping parameter values from net-level to task-level and back again, task (and case) parameters may be assigned values directly from an external data source on starting and be directly mapped back on completion. External data sources are accessed via a specific *Data Gateway*. To see a list of available data gateways, choose the 'Data Gateway' tab in the Update Task Parameter dialog (Figure 4.34).

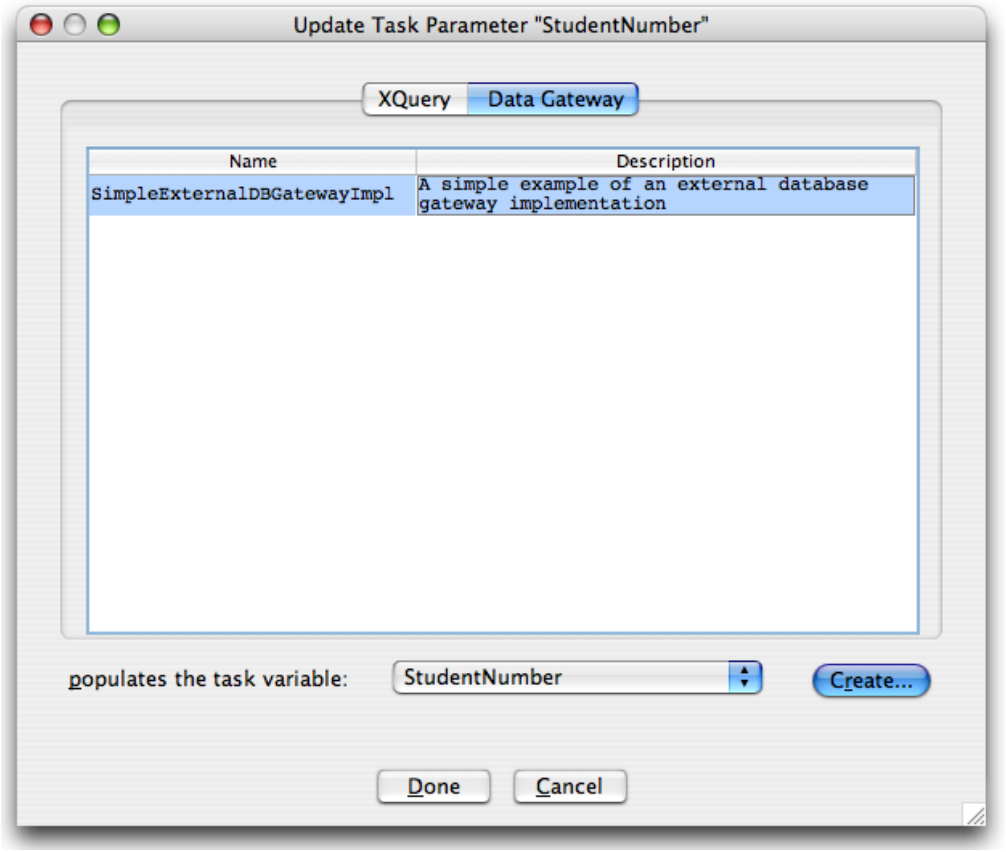


Figure 4.34: The Data Gateway tab

Figure 4.34 shows a single data gateway in the list (SimpleExternalDBGateway, an example gateway that ships with YAWL) – any other gateways defined for particular specifications will also be listed here (see *Note* below). The combo box at the bottom of the dialog shows which parameter will receive the data from the gateway selected. When the Done button is clicked, the selected gateway will be displayed as a special external mapping expression in the Update Parameters dialog (Figure 4.35).

A case-level external data gateway may also be chosen, so that each time a case is started for a specification the chosen data gateway will be called to populate its case-level variables, and when each case completes, the data gateway will be called to update output values from the case back to the specified external data source. To choose an external data gateway at the case level, select **Net – Set Starting Net...** from the main menu, then choose the desired external data gateway from those listed in the dropdown on the dialog that displays (Figure 4.36).

Note: Specific data gateways must be created for each specification that wishes to access an external data source directly. How to create a data gateway is outside the scope of this manual. Please refer to the YAWL Technical Manual for details.

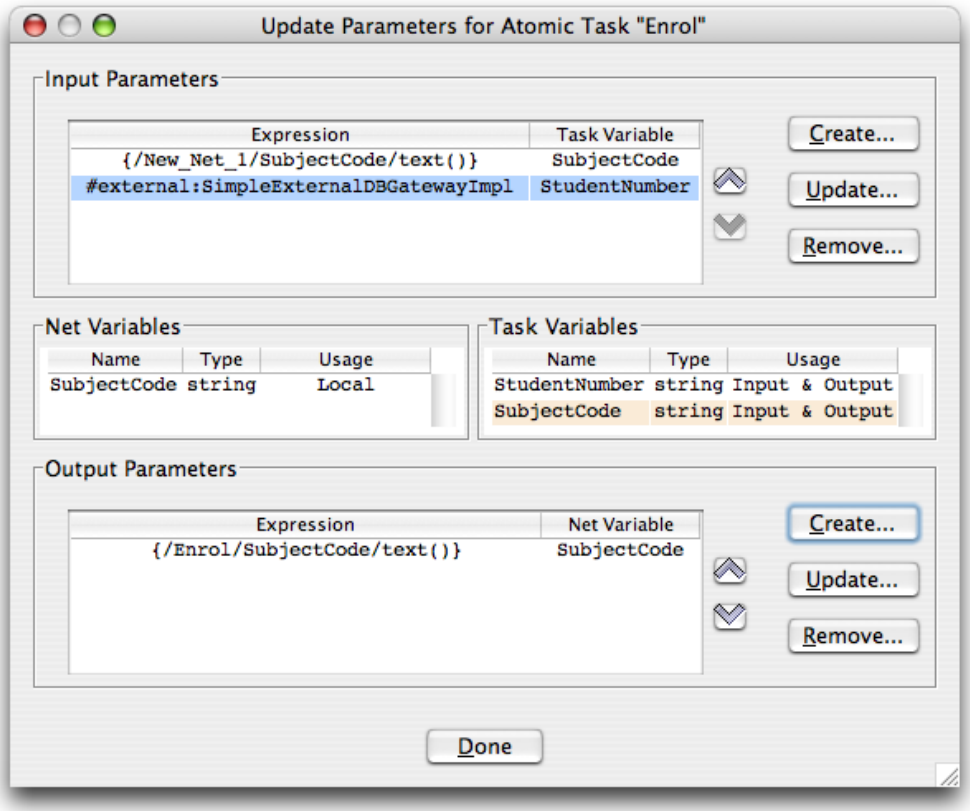


Figure 4.35: Established task parameters with external mappings

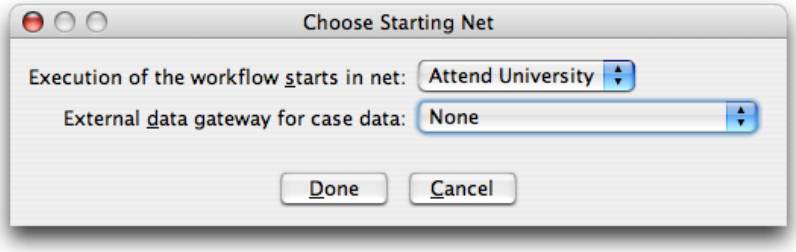


Figure 4.36: Setting an external data gateway from case start and completion

Notes about parameters:

- For simple assignments, such as those in Figure 4.33, the XQuery expressions for the input parameters follow the form {/name_of_net/name_of_variable/text()} and are mapped to a task variable, while those for output parameters follow the form {/name_of_task/name_of_variable/text()} and are mapped to a net variable.
- An *Input* Usage mode means that the variable requires a value to be mapped into it when its task starts (via an input parameter). An *Output* Usage mode means that the variable is required to map a value from it (typically to a net-level variable) when its task completes (via an output parameter). An *Input & Output* Usage mode combines both requirements.
- Only Net-level variables may have a Usage mode of *Local*, which signifies a scope within the net but not external to it. Thus, sub-nets require net-level variables with modes other than *Local* to support

data passing to and from their parent nets. A root (or top-level) net with variables of type *Input Only* or *Input & Output* will, when started, request values for those variables from a user via a form, before the first task in the net is activated. No action is taken for Output modes set for root net variables.

- Input parameters may only be created for variables of mode types *Input Only* or *Input & Output*.
- Output parameters may only be created for variables of mode types *Output Only* or *Input & Output*.
- A single task may map some parameters via XQuery and other parameters via external data gateways (as in Figure 4.35).

4.5.8 Flow Detail

When dealing with tasks that have XOR and OR splits, we need some way of defining which flows should be activated at runtime. This is achieved by associating a boolean XQuery expression with each flow. At runtime, the flow expressions are evaluated and:

- if the split type is an OR-split, *each* flow that has an expression that evaluates to true will be executed.
- if the split type is an XOR-split, the *first* listed flow that has an expression that evaluates to true will be executed.

Since it is possible that all flow expressions evaluate to false, XOR and OR splits must nominate a *default* flow, which will activate if all of the other flow expressions evaluate to false, to ensure that the workflow does not deadlock (i.e. is not blocked at that point from proceeding and eventually completing). Default flows are defined by prioritising the order in which the various flows of a split are evaluated – the one prioritised last in the order becomes the default flow.

To update the flow detail of a task that has a split, right click on the task and choose **Update Flow Detail...**. The "Flow Detail" dialog appears, which list the flows coming out of the split and each flow's corresponding Predicate (or flow expression).

The arrowed buttons to the right of the list allow you to reorder the evaluation sequence of the predicates, so that the default predicate (the one you want to activate when all others fail) can be placed at the bottom of the list. Carefully ordering the evaluation sequence is especially important when dealing with an XOR-split, because only the first that evaluates to true will be activated, and all subsequent flows will be ignored.

The currently selected flow in the dialog will be identified by being highlighted green in the Net (Figure 4.37).

To specify a predicate for a particular flow, select the flow from the list and click on **Predicate...**. Enter a predicate as a boolean XQuery expression and choose **Done**. (Note that a net-level local integer variable called 'score' has been introduced to the net for the purposes of showing how to create a boolean XQuery expression for a flow predicate; it is not used again in this tutorial).

Timer Predicates

Timer predicates are special (non-XQuery) expressions that may be used as flow predicates. For each task that has a timer associated with it (cf. Section 4.12) an implicit, net-level timer-state variable is created and maintained at runtime. At any particular time during the execution of the net, a timer-state variable can have one of four values (Table 4.1).

A timer predicate can have one of two operators, **=** (equals) or **!=** (not equals), and takes the form:

timer(*name_of_task*) operator '*timer-state*'

For example, assuming a task called 'Enrol' has a timer, then on any outgoing flow from an OR-split or XOR-split in the net that contains the 'Enrol' task, the following example timer predicates are valid:

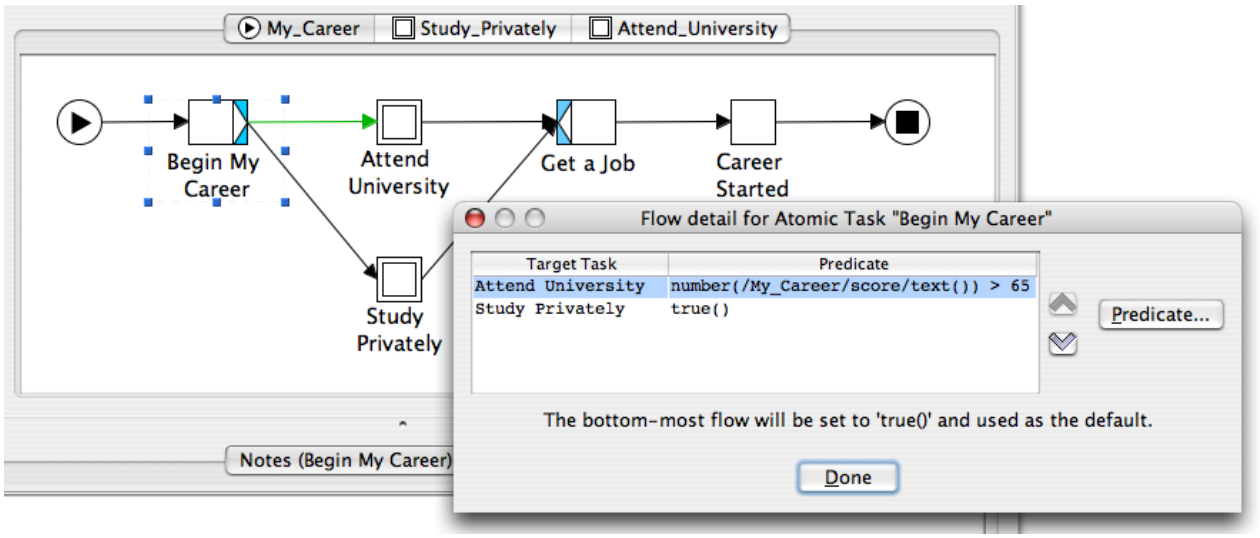


Figure 4.37: Updating Flow Detail

dormant	Timer has not yet started
active	Timer is running
closed	Task completed before timer expired
expired	Timer expired before task completed

Table 4.1: Valid states of timer state variables

- timer(Enrol) = 'dormant'
- timer(Enrol)='expired'
- timer(Enrol) != 'expired'

Note: Timer predicates are case-sensitive (including the 'timer' keyword, the name of the task and the state value).

4.5.9 Multiple Instance Queries

Now that we have an understanding of parameter setting and XQueries, we can revisit, from a data perspective, parameter setting for the particular requirements of Multiple Instance (MI) Tasks. In general terms, an MI task receives, as input from a net-level variable mapping, a variable of complex type, typically a list of some other data type (but more complex constructions are of course supported too), which it then *splits* into a number of logically distinct data values, to form the data that is assigned to each task instance. When the MI task completes, it gathers all the individual pieces of data from the various task instances and reconstructs the complex type variable so that it can be mapped back to the net-level variable.

To illustrate the operation of MI tasks, with particular emphasis on the data perspective, we will use the "List Builder" specification shown in Figure 4.38, which begins by compiling an 'order' – a list of book titles. It then creates a number of MI task instances, one for each book title in the list of books. Once all the MI task instances complete, the updated list is recomposed and shown in the final task.

To prepare this specification, drag two atomic tasks and one MI task onto the canvas. We then need to define a complex data type to store the entire book order. Open the Update Data Type Definitions dialog from the Specification menu, and enter the following two complex type definitions:

```
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema">
```

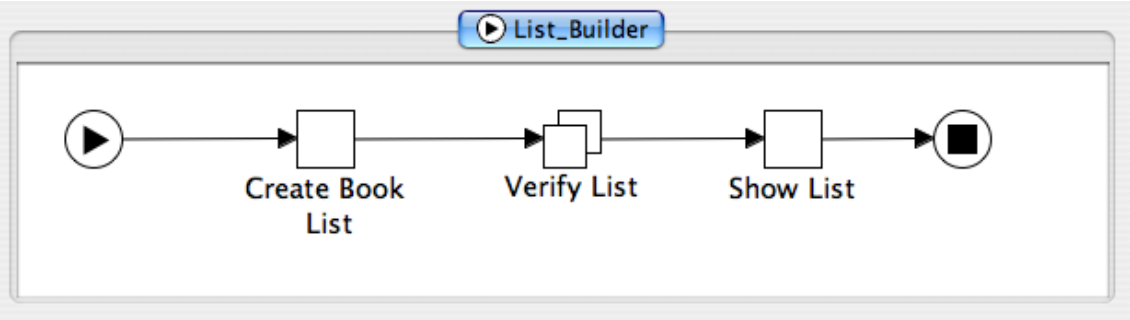


Figure 4.38: Example specification with a Multiple Instance Task

```
  <xs:complexType name="BookOrder">
    <xs:sequence>
      <xs:element name="title" type="xs:string" />
      <xs:element name="price" type="xs:double" />
      <xs:element name="inStock" type="xs:boolean" />
    </xs:sequence>
  </xs:complexType>
  <xs:complexType name="BookList">
    <xs:sequence>
      <xs:element maxOccurs="unbounded" name="order" type="BookOrder" />
    </xs:sequence>
  </xs:complexType>
</xs:schema>
```

The first defines a complex type called 'BookOrder', which is a record with three simple type fields. The second defines a complex data type called 'Booklist', which consists of an array of one or more elements called 'order', of BookOrder type ('unbounded' means there is no upper limit on the number of order records we can include in the book list). Once this is added, we can start populating the data perspective of the specification:

- Create a net-level variable called **MasterList** of type **BookList** and usage **Local** (Tip: In the Update Variable dialog 'Type' dropdown, user-defined types are listed after all the built-in simple types). Give the variable this initial value:

  ```
  <order>
     <title>YAWL User Manual</title>
     <price>0.00</price>
     <inStock>false</inStock>
  </order>
  ```

  When entered correctly, the text will become green to show that it is a valid value to assign to the Masterlist variable of complex type 'BookList', since it defines values for the elements of one BookOrder. It is important that an initial value is provided for this variable, because our definition of the 'BookList' type specifies that it will contain at least one element (that is, because it doesn't include a 'minOccurs=0' clause). If there was no initial value specified for this type, the specification would fail schema validation at runtime – in other words, the Engine will reject the specification.

- Add a decomposition to the first atomic task, and call it 'Create Book List'. Add to the decomposition a variable called **bookList** of type **BookList** and usage **Input & Output**. Then, open the Update Parameter Mappings dialog, add an input parameter mapping the net-level Masterlist variable to the task's bookList variable, and an output parameter to map it back again (see Figure 4.39). This task will allow a user to add any number of book orders to the master book list.

- Add a decomposition to the other atomic task, and call it 'Show List'. Add a variable to the decomposition similarly to the first task, except that the usage should be **Input Only**, and so only an

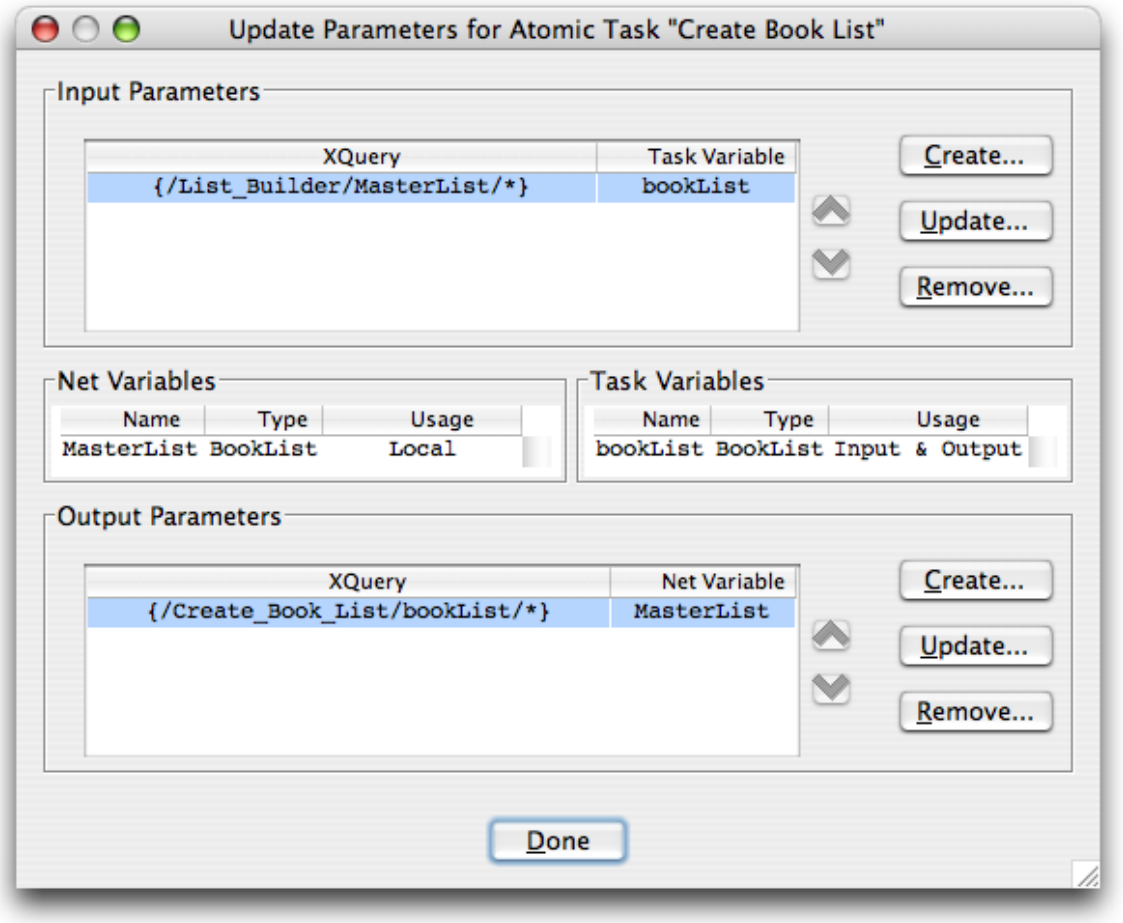


Figure 4.39: Update Parameter Mapping dialog for task 'Create Book List'

input parameter mapping is required. This task will show the user the results of any data changes done during the execution of the MI task, thus its variable is input only (meaning that the values are 'display-only').

- Add a decomposition to the MI task and call it 'Verify List'. To the decomposition, add a variable called **book** of type **BookOrder** and usage **Input & Output**. Note carefully that the task variable we have added to the decomposition is of BookOrder type – in our data definition we have defined the BookList type being comprised of a number of BookOrder type elements – so what has been defined in this decomposition is a mapping of a single BookOrder to each task instance that will be created when the MI task is executed.
- The mapping of input and output parameters for MI tasks is done a little differently to atomic (single instance) tasks, and involves a two stage process. Open the Update Parameter Mapping dialog for the MI task 'Verify List' and add the input and output parameter mappings as seen in Figure 4.40. Notice that the input parameter maps the entire net-level variable 'MasterList' to 'book', a single task-level BookOrder variable, while the output parameter maps the contents of the 'book' variable, wrapped in 'order' tags, back to the net-level 'MasterList'. These kinds of mappings would be invalid for a single-instance task, but here we need to define a mapping that on input takes a net-level list, assigns each member of the list to a task instance, and on output takes each task instance's variable and maps it back to the net-level list. The intermediary steps that allow this mapping to occur is done in the second stage of the mapping process.
- Right click on the 'Verify List' MI task and choose **Set Instance Detail...** from the popup menu. On

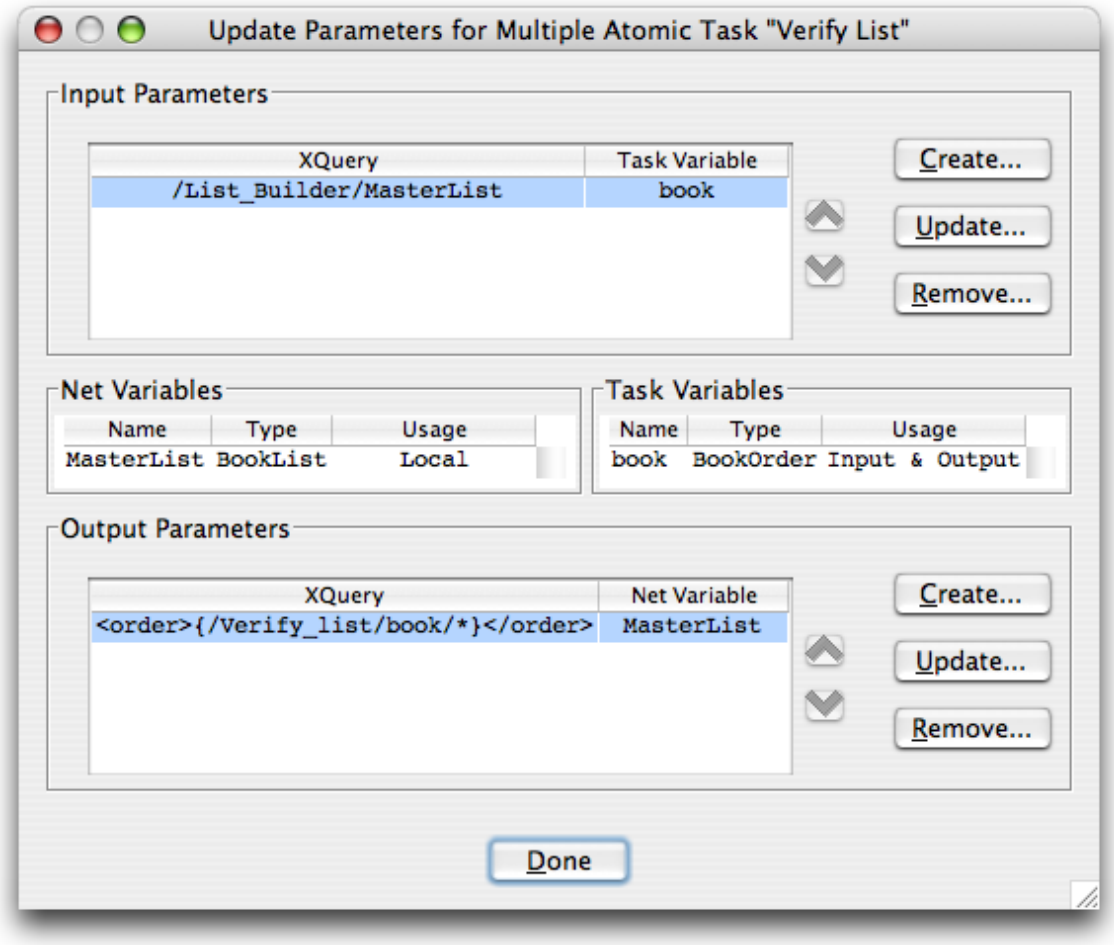


Figure 4.40: Update Parameter Mapping dialog for MI task 'Verify List'

the **Bounds** tab page, set minimum instance to 1, maximum instances to 20, continuation threshold to 5 and 'static' instance creation type. These settings mean that between 1 and 20 task instances will by started from this MI task at runtime (depending on the number of book orders in the book list), the MI task will complete when 5 instances complete (or all complete if less than 5 were started) and new instances may not be dynamically started after task execution begins.

Now, click the **Queries** tab page. It is here that we will specify how the BookOrders contained in the MasterList variable will be 'split' into individual task variable instances and how those instance variables are 'aggregated' back into the MasterList on completion. Figure 4.41 shows the Queries tab page for the 'Verify List' MI task. There are six parts to this dialog, four requiring XQueries and two variable settings:

- **Multiple Instance Variable**: this specifies the task instance variable that has been defined to accept a single item from the net-level 'list' variable – in our case, the 'book' variable.
- **Accessor Query**: this query defines the source of the data that needs to be split into multiple task instances, in most cases (as in our example) it is a simple XPath expression specifying the net-level variable that is being mapped into the MI task, and exactly matches the input parameter set for the variable in the Update Parameters dialog. In this case, it is `/List_Builder/Masterlist` – note that it is the same XQuery expression as the task's input parameter as shown in Figure 4.40.
- **Splitter Query**: the splitter is an XQuery expression that is used to take the 'list' variable mapped in and 'split' it into a number of 'child' elements, one for each member of the list. In natural lan-

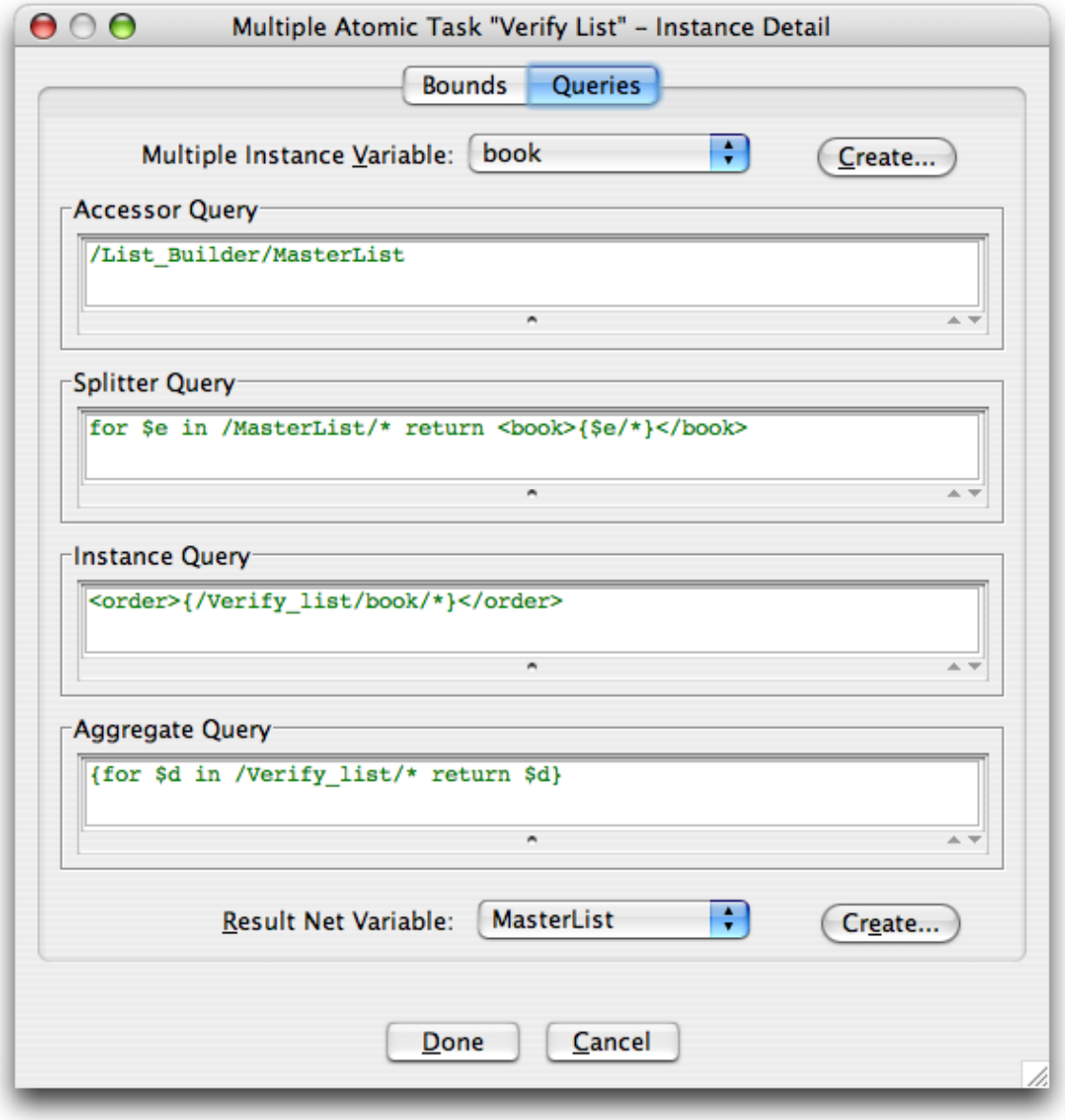


Figure 4.41: Set Instance Detail dialog, Queries tab for MI task 'Verify List'

guage, the query reads "for each element in the accessor variable, return that element". In our example, the XQuery is: `for $e in /MasterList/* return <book>{$e/*}</book>` The $e part is a query variable – all query variables start with a $ sign followed by one or more characters ($e is a convention for a loop variable, but other names are, of course, allowed). The return value for each $e in our query would start and end with 'order' tags; since our variable is called 'book', we have to replace the 'order' tags with 'book' tags, so the return value of our XQuery is the *contents* of the order ({`$e/*`}), but surrounded by 'book' tags. The final result is a number of 'book' values, each corresponding to one 'order' element in MasterList.

– **Instance Query**: this query defines how the 'book' variable within each task instance should be formatted prior to being mapped back to the net-level MasterList. Like the splitter query above, we need to replace the surrounding 'book' tags with 'order' tags, the contents of the element being the *contents* of the 'book' variable ({/Verify_list/book/*}). Notice also that this query exactly matches the task's output parameter in Figure 4.40.

- **Aggregate Query**: puts all the instance query results into a list (in this case, a list of 'order' elements) ready for mapping back to the net-level variable. The aggregate query will look exactly like this in most cases, except that the outermost braces are optional. ($d is used simply to differentiate it from $e in the splitter query, but its name is unimportant).
- **Result Net Variable**: this specifies the net-level variable to which the results of the aggregate query is to be mapped.

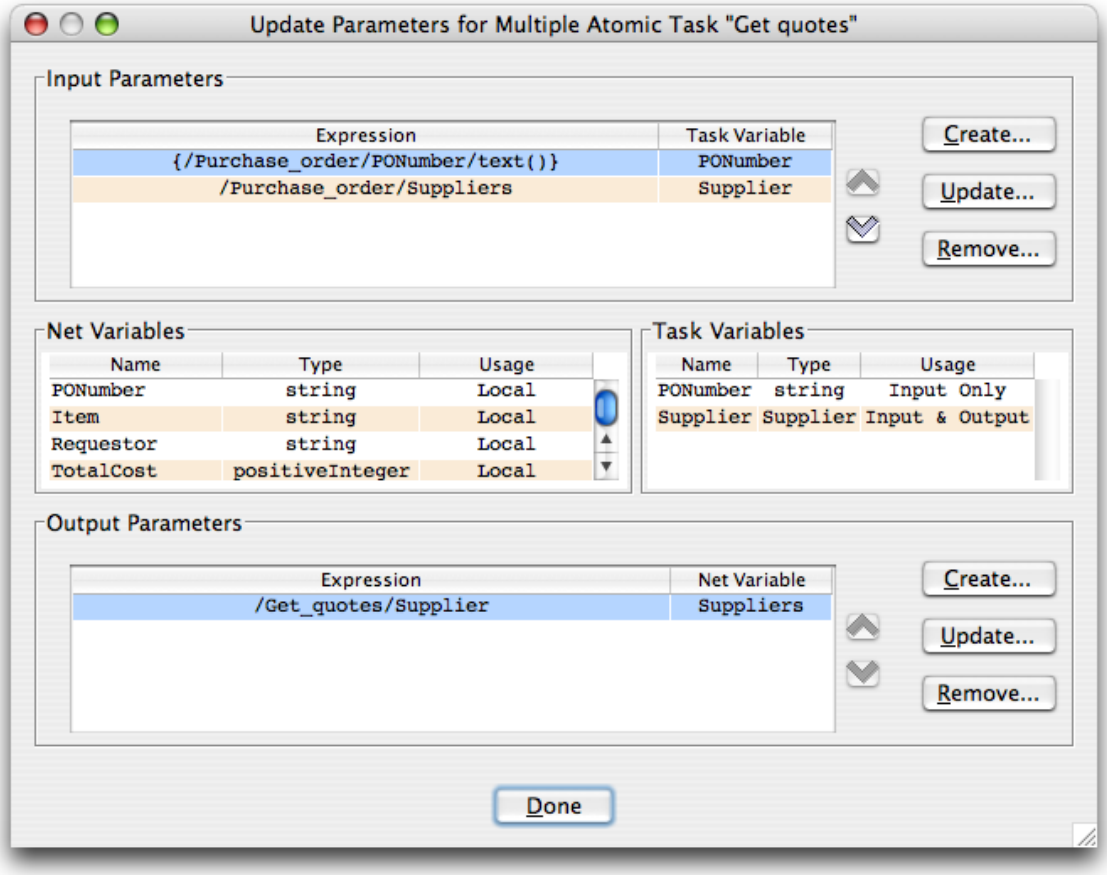


Figure 4.42: Update Parameters dialog, 'Get Quotes' task

When this specification is executed, it will first allow the user to specify a number of book orders, then will split the details of each into a corresponding number of MI task instances, one for each order. The price and availability of each order can be updated within its own task instance. When all (or the threshold) of MI task instances have completed, their data will be aggregated back into the list for display in the third and final task.

For a second example, consider a process that raises a purchase order to purchase a particular product. The business rules for this process require that at least three quotes are needed for any purchase, from which one is chosen to fill the order. A multiple instance task called *Get Quotes* is used to gather the product quotes from suppliers. The Update Parameters dialog for the *Get Quotes* task can be seen in Figure 4.42.

The task has two variables defined: 'PONumber' (the purchase order number) and 'Supplier' (the details of a single supplier). Notice that 'PONumber' is defined as *Input Only*, and is mapped from the net-level variable of the same name – this means that the purchase order number will be displayed within each of the workitems created from the MI task. Notice also that while a list of Suppliers is mapped in from a net-level variable, the mapping expression maps to a single supplier – one for each task to be created. Also, the Output Parameter mapping takes a single Supplier from the task and maps it to the net-level list of Suppliers.

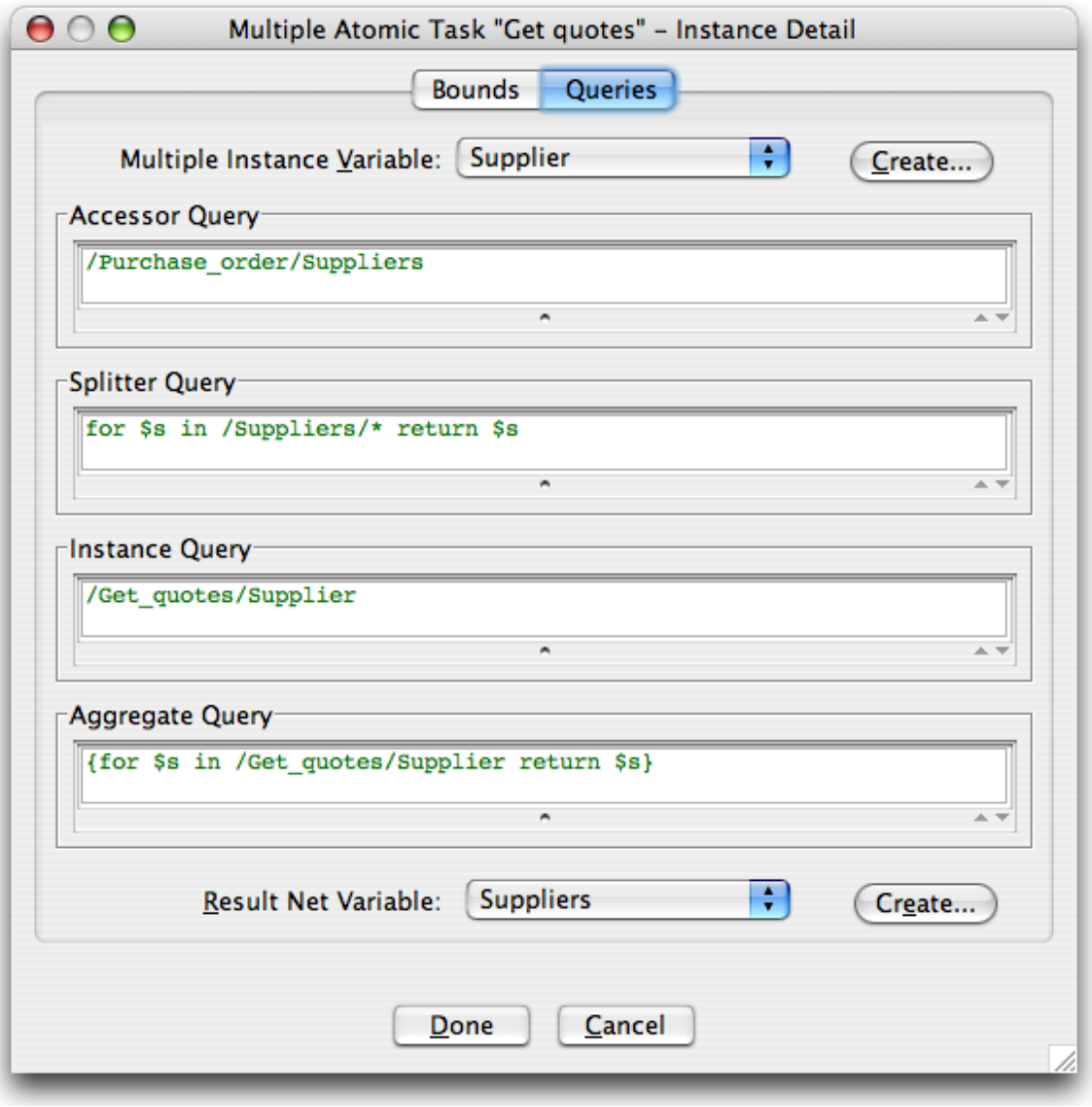


Figure 4.43: Instance Detail dialog for the 'Get Quotes' MI task

The MI queries for the task can be seen in Figure 4.43. Again, note that the Accessor Query exactly matches the Input Parameter Expression, and the Instance Query exactly matches the Output Parameter Expression, as can be seen in Figure 4.42. The Splitter Query in this example is a little simpler than the earlier one, since we don't have to worry about different tag names for the split data because out task-level variable has the same name as its data type, so it takes the less complicated form **for $s in /Suppliers/* return $s** (for each Supplier in the list of Suppliers return that Supplier). The Aggregate Query takes the same form as the previous example.

When the instance creation type is set to **dynamic**, then new instances of the MI task may be created at runtime *after the task execution has begun and split into its instances*. There is a button on the default worklist handler to accommodate this (see Chapter 6), which will be enabled for dynamic MI tasks until such time as the maximum instances bound has been met.

4.5.10 Fast-Tracking Data Definition

If all of a task's input and output parameters will involve a simple mapping to and from net-level variables, a "fast-track" can be taken to do it all in a few mouse clicks. To achieve this, right-click on an atomic task that does not yet have a decomposition, and select **Decompose to Direct Data Transfer**. The dialog in Figure 4.44 will appear.

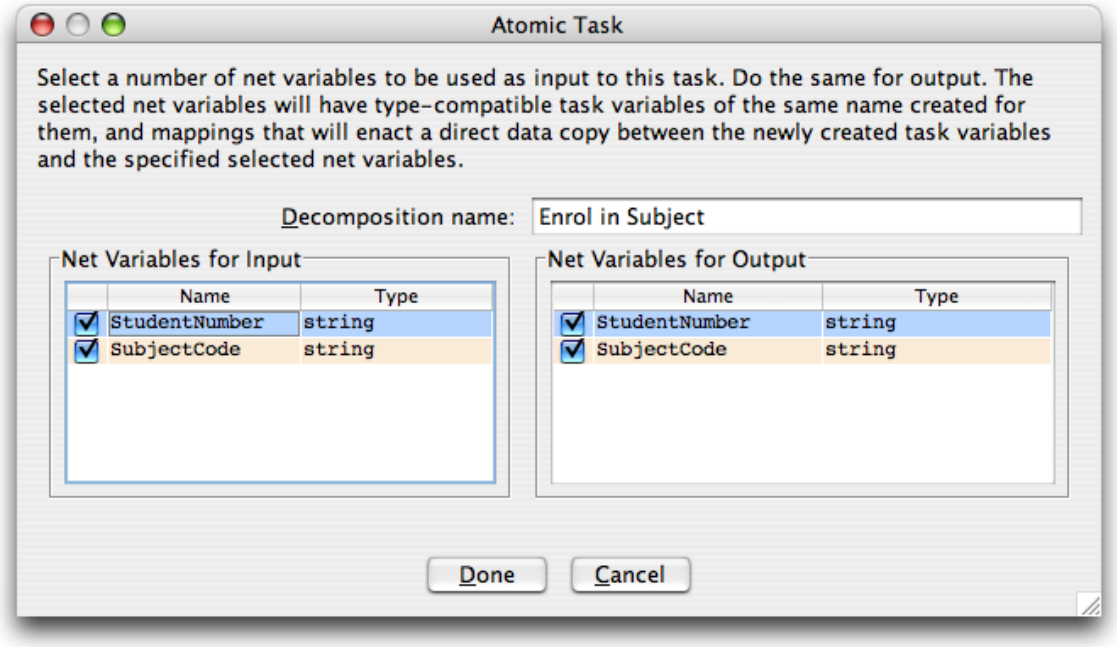

Atomic Task
Select a number of net variables to be used as input to this task. Do the same for output. The selected net variables will have type-compatible task variables of the same name created for them, and mappings that will enact a direct data copy between the newly created task variables and the specified selected net variables.
Decomposition name:
Enrol in Subject
Net Variables for Input
Name
Type
StudentNumber
string
SubjectCode
string
Net Variables for Output
Name
Type
StudentNumber
string
SubjectCode
string
Done
Cancel

Figure 4.44: An example of the direct data transfer dialog

All of the available net-level variables for the task's containing net will be listed in the dialog. Simply check the boxes for the desired inputs and outputs. This dialog will automatically create a task decomposition and matching XQueries to directly transfer data from a selected net variable to a task variable of the same name and back again.

4.5.11 End of Scenario

This is where our scenario ends. The My Career Scenario was designed to outline the basic the functions of the YAWL Editor and to provide you with a understanding of designing a YAWL workflow specification.

But the functionality of the YAWL Editor does not stop here. If you are after something more challenging, try adjusting your version of the scenario to expand into more sub-Nets and more complex situations.

4.6 Connections

4.6.1 Connecting to the YAWL Engine

Each atomic task in a YAWL specification must be associated with a 'service' that will be responsible for performing the work of the task. If you do not explicitly specify a service for a task, by default the task will be assigned to the *Default Worklist Handler*, which by default is supplied by the Resource Service. If you want to associate a task with a service other than the Default Worklist Handler, you can make the appropriate choice from a list in the task's decomposition dialog (see the following section). The Editor populates the list of available services by making a call to a running Engine, which returns the list of services currently

registered with it. Before this can occur, the Editor must first establish a valid connection to a running Engine.

On Editor startup, a connection to a running Engine is attempted. If successful, the Engine connection icon at the left of the status bar will turn green. If unsuccessful (perhaps because the Engine is not running, or the connection parameters are incorrect) the connection icon will show red. After the Editor has started, an Engine connection may be performed via the Settings menu.

To establish a connection with a running YAWL Engine:

1. Click the **Settings** Menu and choose the **Engine Connection ...** item.
2. From the resulting dialog (Figure 4.45), accept the default values or enter the following engine details:
   - YAWL Engine URI;
   - Administrator's User Name;
   - Administrator's Password.

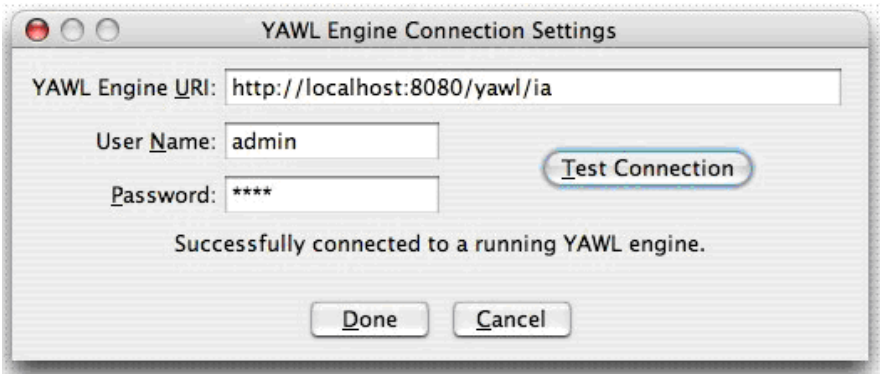


Figure 4.45: Specifying the YAWL Engine connection detail

The YAWL Engine URI value is set by default to a locally installed Engine (`http://localhost:8080/yawl/ia`), but should be changed if the Engine is installed remotely. The User Name and Password have the following case-sensitive defaults (but can be changed via the *Client Applications* web-form (Section 6.4.4):

- user name: **editor**
- password: **yEditor**

As a user convenience, a button called **Test Connection** is supplied, which will test a connection to a running engine with the detail supplied for correctness before you are committed to using those details for any further editor/engine interactions. To finalise the connection settings, click the Done button.

4.6.2 Connecting to the Resource Service

To use the organisational data managed by the Resource Service for assigning tasks to Participants or Roles, a connection between the editor and the Resource Service needs to be established.

Like the Engine connection (above), when the Editor starts a connection to a running Resource Service is attempted. If successful, the Resource Service connection icon at the left of the status bar will turn green. If unsuccessful (perhaps because the Service is not running, or the connection parameters are incorrect) the connection icon will show red. After the Editor has started, a Resource Service connection may be performed via the Settings menu.

To set the Resource Service connection details:

1. Click on the **Settings** menu and choose the **Resource Service Connection...** item.
2. From the resulting dialog (Figure 4.46), accept the default values or enter the following engine details:
   - YAWL Engine URI;
   - Administrator's User Name;
   - Administrator's Password.

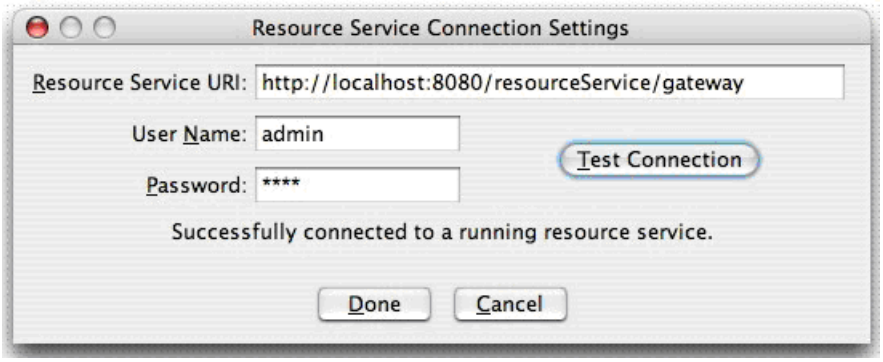


Figure 4.46: Specifying the Resource Service connection

The Resource Engine value is set by default to a locally installed Resource Service (`http://localhost:8080/resourceService/gateway`), but should be changed if the Engine is installed remotely. The User Name and Password have the following case-sensitive defaults (but can be changed via the *Client Applications* web-form (Section 6.4.4):

- user name: **editor**
- password: **yEditor**

4.6.3 Connecting a Decomposition to a registered YAWL Service

You can use task decompositions within your workflow to make a connection to custom YAWL services that have been registered with a running engine. By associating a task decomposition with a custom service, all task instances based on that decomposition will be passed to the custom service at runtime for processing – that is, the custom service is responsible for performing the work of the task instance.

For example, a decomposition may be set up to place an order with an external company. Upon execution of any task using this decomposition, data could be transmitted via a Web Service invocation to this company.

To have a decomposition invoke custom YAWL service, do the following:

1. Right-click on a task, the choose **Task Decomposition Detail...**. An Update Task Decomposition dialog box will appear (see Figure 4.30).
2. In the "YAWL Registered Service Detail" panel, Select the required Web Service from the dropdown list of those available in the Engine.
3. Click **Done** to finish.

If the Editor is connected to a valid running YAWL Engine instance, the YAWL Service Dropdown Box will contain entries for all custom YAWL services the engine has registered. Otherwise, only the Default Worklist (of the Resource Service) will be available.

When you select a YAWL Service, the Editor will query this running engine for the mandatory input and output variables required by the service (if any), and will populate the decomposition variables of the selected

task with those variables. Core custom services that are supplied with the engine include one for RPC-Style Web Service Invocation (WSInvoker Service), and one for supporting flexibility and exception handling for YAWL processes (Worklet Service). Optional services include an SMS handler, a digital signature service and a email sender service.

4.7 Validating and Saving a Specification

At any stage you can validate and/or save your specification to a YAWL Engine file (.yawl).

To validate your specification:

1. Click the Validate button, , on the Menu Toolbar or click **Specification** on the Menu and choose **Validate Specification...**.
2. If problems are detected, a table listing them will appear at the bottom of the Editor with details of any inconsistencies that would stop the specification from running in the YAWL Engine. Figure 4.47 show a specification with no validation problems. Figure 4.48 shows an example invalid specification, where the Validation Problems table shows that the 'Bad Task' task has no outgoing flow, and is not on a path between the input and output conditions.

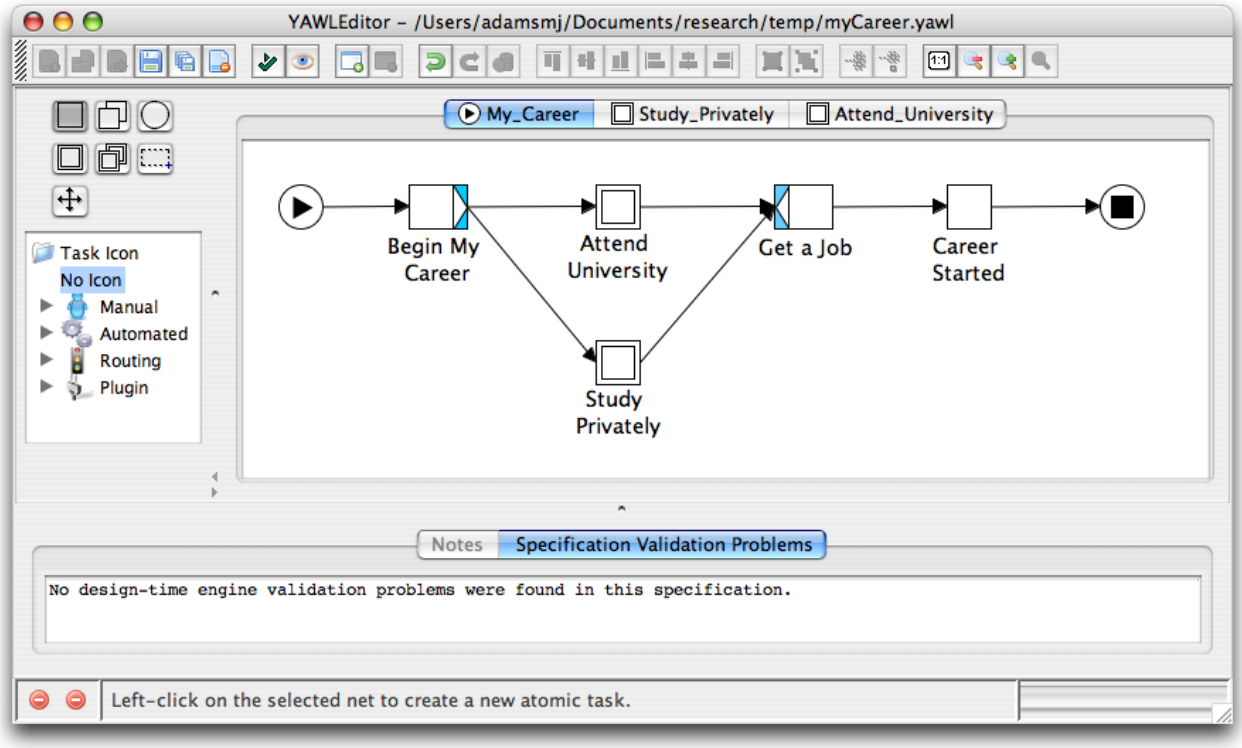


Figure 4.47: A valid specification

To save your specification to file:

1. Click on the Save button, , on the Menu Toolbar or click **Specification** on the Menu and choose **Save Specification...**. The 'Specification File Save Options' dialog appears (Figure 4.49).

   If this is the first time the specification has been saved, and a 'Specification ID' has not yet been entered via the 'Update Specification Settings' dialog, a 'Specification ID' field will appear in the dialog

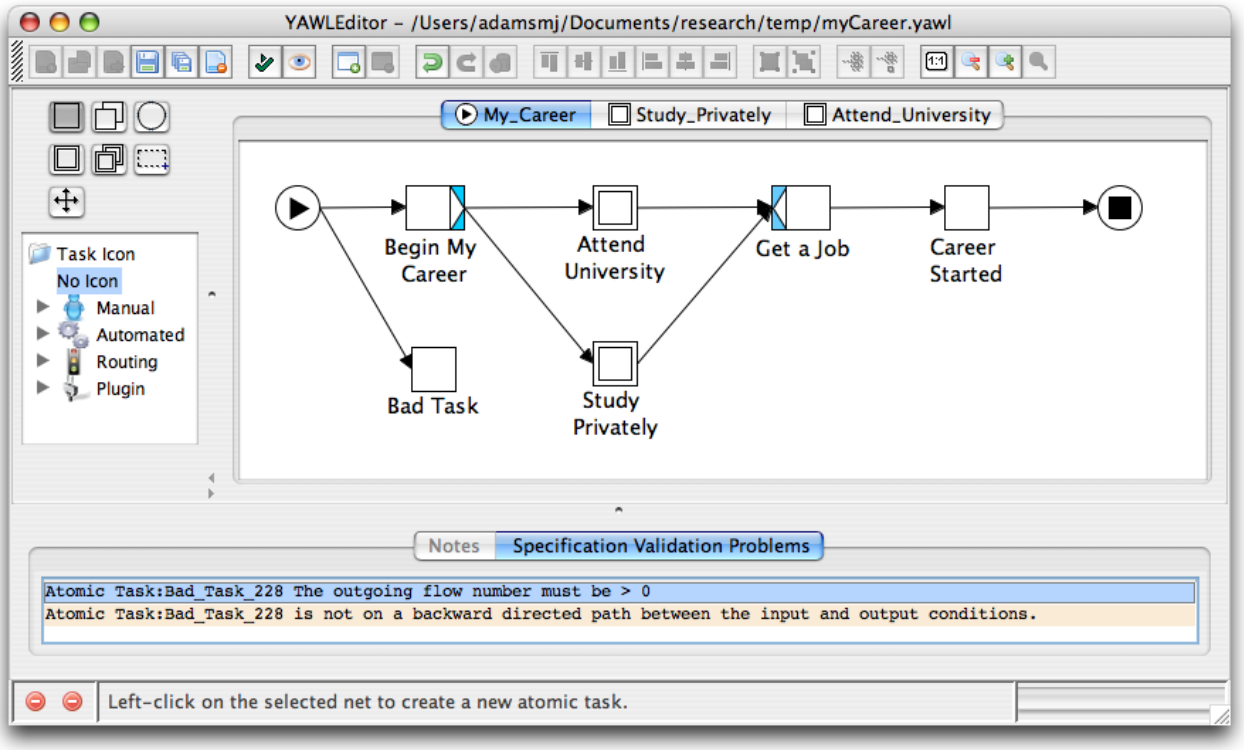


Figure 4.48: A invalid specification

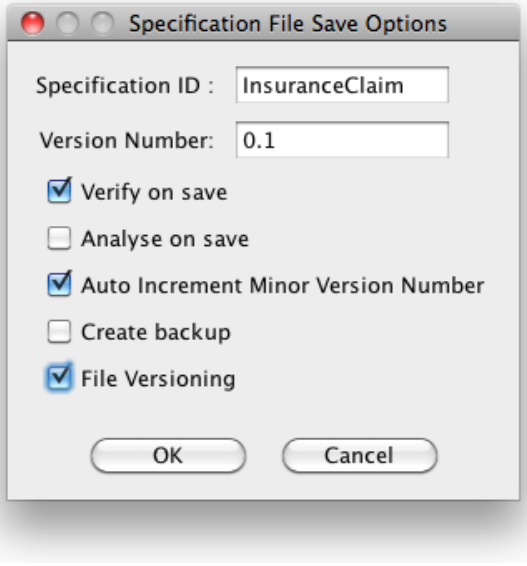


Figure 4.49: Specification File Save Options dialog

(all Specifications must be given a valid ID). The ID can be a combination of alphanumeric characters and the underscore, but cannot start with a numeric character. Once set, this field will not reappear in subsequent saves of the specification.

The 'Version Number' field provides a version number for the specification. Version numbering al-

lows different versions of the 'same' specification to co-exist in the Engine. YAWL specification version numbers consist of a major part (to the left of the point) representing a major revision, and a minor part (to the right of the point) representing a minor revision. Version numbers begin at 0.1; you may edit the version number directly to a *higher* version number at any time. If the 'Auto Increment Minor Version Number' checkbox is checked, the minor revision will increase by one each time the specification is saved.

The 'Verify on save' and 'Analyse on save' checkboxes, if checked, will verify and and/or analyse the specification before it is saved, providing a final check of the specification (note: verification and analysis may take some time for large and/or complex models, and analysis in particular should be unchecked for incremental saves of such models).

The 'Create backup' checkbox, if checked, will copy the previous version of the specification file to a file of the same name, but with a .bak extension. Checking this option is recommended.

The 'File Versioning' checkbox, if checked, will copy the previous version of the specification file to a file of the same name with the version number appended to it, so that an archive of each and every version of a specification can be maintained. For example, if you have a specification called 'InsuranceClaim.yawl', each time a version of the file is saved, a copy of the previous version will be created called 'InsuranceClaim.0.1.yawl', 'InsuranceClaim.0.2.yawl', and so on.

Once the dialog is completed, click **OK** to save the file.

This saved specification file can now be loaded into a running YAWL Engine and executed.

To import a specification file from a pre-2.0 version of the editor (i.e. a .ywl file):

1. Click on the "Import a YWL Specification file" button, , on the Menu Toolbar or click **Specification** on the Menu and choose **Import from YWL File...**.

   A window will appear asking you specify the YWL file to import.

2. Select the file and choose **Open**.

   The YWL file will be loaded and converted to a YAWL 2.0 version specification. The specification can now be edited and saved as a 2.0 specification in the usual way.

4.8 Specification Analysis

Verification of specifications for the engine only determines whether the engine will be able to successfully load and begin execution of the specification. In contrast, the analysis tool can be used to test for deeper issues in the specification.

The analysis toolbar button, , or the matching **Analyse Specification** menu item under the **Specification** menu allows workflow designers to analyse their specifications. A number of potential problems with a workflow can be automatically spotted with analysis. Examples include spotting potential deadlock situations, unnecessary cancellation set members, and unnecessary or-join decorators (at run-time, or-joins require significant processing effort, and should be removed or replaced with other join types if they are not actually needed).

A configuration dialog for specification analysis is available via the **Tools** menu, **Configure Specification Analysis** (see Figure 4.50). Note that many of the options are disabled by default since they are resource intensive and may take some time to complete for large and/or complex workflows. It is recommended that analysis of such specifications not be done incrementally, but rather at planned checkpoints during specification development.

Because analysis make take a long time and is very resource intensive, it may appear that the Editor has frozen during an analysis (although it is very unlikely that this will actually be the case). To provide some feedback about the progress of the analysis, a dialog will appear which shows updates and messages (see Figure 4.51). At any time, you may click the 'Stop' button in the dialog to abort the analysis. The dialog also includes a checkbox that, when checked, will keep the dialog open after the analysis completes so that the messages may be noted. This functionality can also be controlled via a setting in the Configure Specification Analysis dialog (see Figure 4.50).

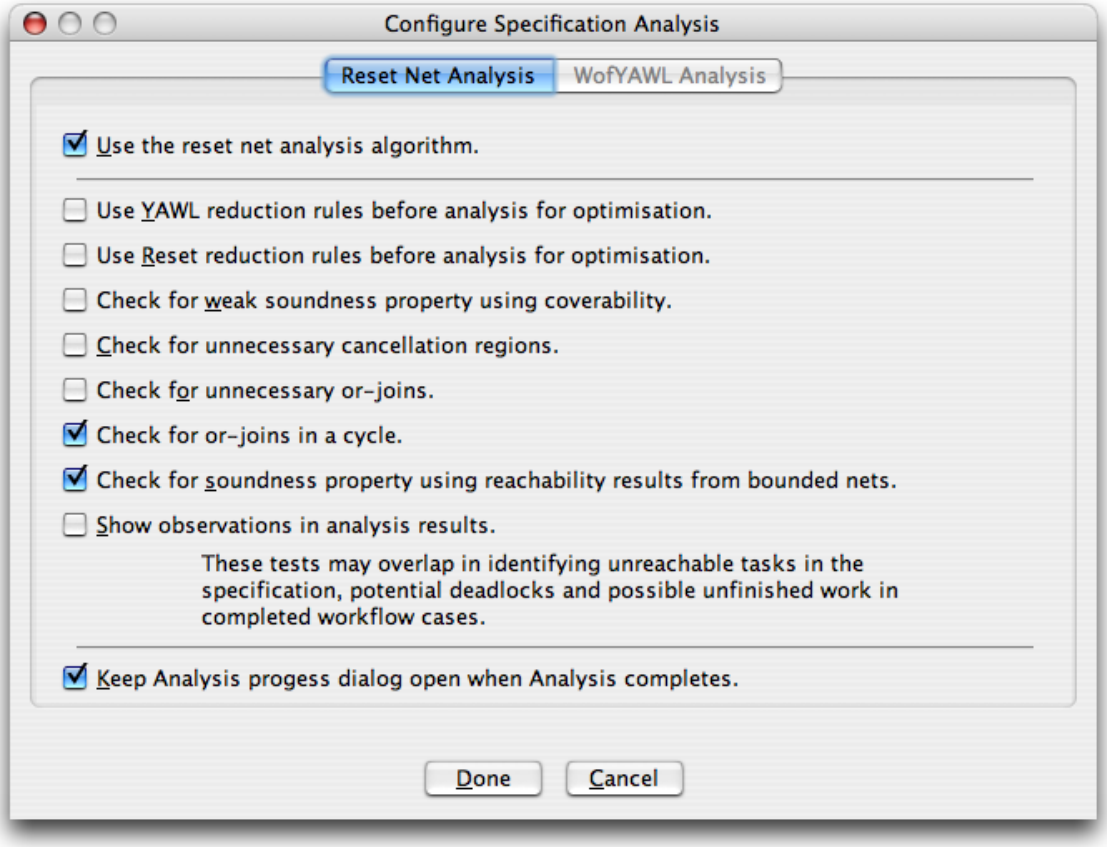

Configure Specification Analysis
Reset Net Analysis
WofYAWL Analysis
Use the reset net analysis algorithm.
Use YAWL reduction rules before analysis for optimisation.
Use Reset reduction rules before analysis for optimisation.
Check for weak soundness property using coverability.
Check for unnecessary cancellation regions.
Check for unnecessary or-joins.
Check for or-joins in a cycle.
Check for soundness property using reachability results from bounded nets.
Show observations in analysis results.
These tests may overlap in identifying unreachable tasks in the specification, potential deadlocks and possible unfinished work in completed workflow cases.
Keep Analysis progess dialog open when Analysis completes.
Done
Cancel

Figure 4.50: Configure Specification Analysis dialog

If the optional YAWL specification analysis utility **wofyawl.exe**, is supplied in the same directory as the Editor, an extra tab entitled **WofYAWL Analysis** will be enabled in this dialog, allowing more analysis options than those supplied by default. The utility must be compiled for specific architectures[3]. The current version of the Editor needs version 0.4 of the utility.

4.8.1 Verification and Analysis Explained

This section provides a brief overview of verification in YAWL. Verification is concerned with the design time detection of certain undesirable characteristics in process models.

Extensive research has been conducted in the area of workflow verification. One of the pioneers of this work is Wil van der Aalst. He formally defined the notion of *soundness* as a correctness notion for workflow nets. This class of Petri nets forms a predecessor of YAWL, which does not support OR-splits/joins, Multiple Instance Tasks and cancellation regions. Informally speaking a workflow is sound iff [4]:

[3] WofYAWL is currently only available for Windows environments.

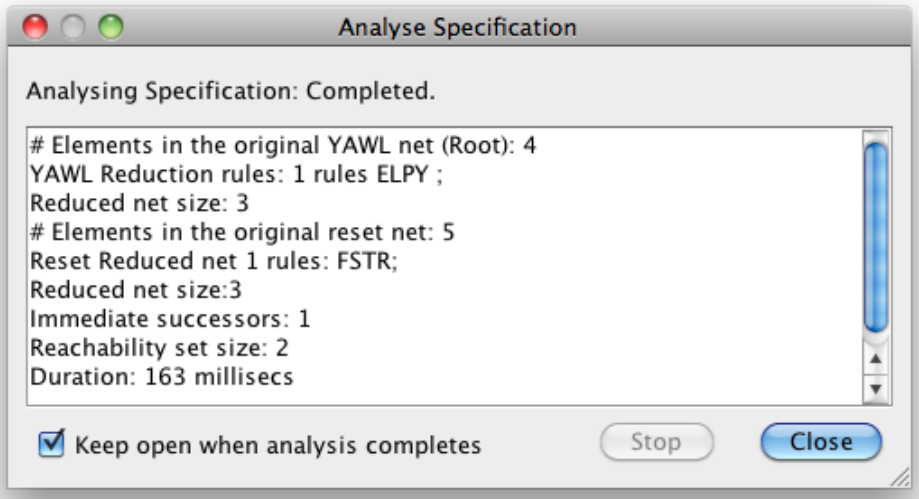

Analyse Specification
Analysing Specification: Completed.
Elements in the original YAWL net (Root): 4
YAWL Reduction rules: 1 rules ELPY ;
Reduced net size: 3
Elements in the original reset net: 5
Reset Reduced net 1 rules: FSTR;
Reduced net size:3
Immediate successors: 1
Reachability set size: 2
Duration: 163 millisecs
Keep open when analysis completes
Stop
Close

Figure 4.51: Analysis progress dialog

- The net has the *option to complete*. That means that from every reachable state the final state, where there is a single token in the output condition, can be reached.
- The net has *proper completion*. This means that when the output condition is marked there are no other tokens anywhere else in the net.
- The net has no *dead tasks*. These are tasks that cannot be executed in any scenario.

For YAWL, the notion of *weak soundness* was introduced as it can be theoretically proven that soundness is not decidable [25]. For a finite state space, we can simply try and check all reachable states, but this is obviously not possible when this state space is very large or infinite. In those cases, we can check whether it is possible to reach the final state from the initial state. Hence, does a scenario exist where we reach the final state?

The richer concepts offered by YAWL also introduce additional correctness notions. For example, an analyst may have used an OR-join where an XOR-join or an AND-join could have been used. This is not desirable for computational reasons, but also because it makes the process model harder to understand. Hence, the YAWL environment will check whether all OR-joins are *immutable*. Another correctness notion is that of *irreducible cancellation regions*. Here it is checked whether certain conditions or tasks can be removed from a cancellation region as they will never contain a token or will never be active when the associated cancellation task executes.

The YAWL editor offers two different approaches to automated verification. One approach [25] is based on the theory of Reset nets (this is built into the Editor). The other approach [23] uses Petri net theory and in particular, the concept of transition invariants. For this latter approach the program wofYAWL is to be used (the executable of this program should be put in the same directory as the Editor under the name wofyawl0.4.exe). These approaches are different in that there are workflow specifications where one of them can pick up an error which the other approach cannot.

By choosing "Configure Specification Analysis" under the Tools menu in the Editor one can choose what type of verification the YAWL editor needs to perform. As some forms of verification may require quite a bit of time it is important to choose the right approach and generally speaking, it is probably best not to verify every intermediate version of a specification.

The screen shot shown in Figure 4.50 shows the options one can choose for the analysis based on Reset nets. This form of analysis supports the use of reduction rules. YAWL reduction rules can be applied to

the net and Reset net reduction rules can be applied to the Reset net that results from the mapping of a YAWL net. The application of these reduction strategies may significantly reduce the workflow that needs to be analysed, hence it may significantly reduce the time that verification takes. Note that there is overhead associated with performing the reductions themselves. Also worth mentioning is that the soundness check is supported for workflows with a finite state space. The editor caps the state space at a certain number of states and tries to construct the reachability graph for the workflow. If the upper bound is not exceeded the soundness of the workflow can be determined with certainty.

The wofYAWL analysis tab-page of the 'Configure Specification analysis' dialog is shown in Figure 4.52. The reader is referred to [23] for a detailed explanation of the concepts behind this approach to verification.

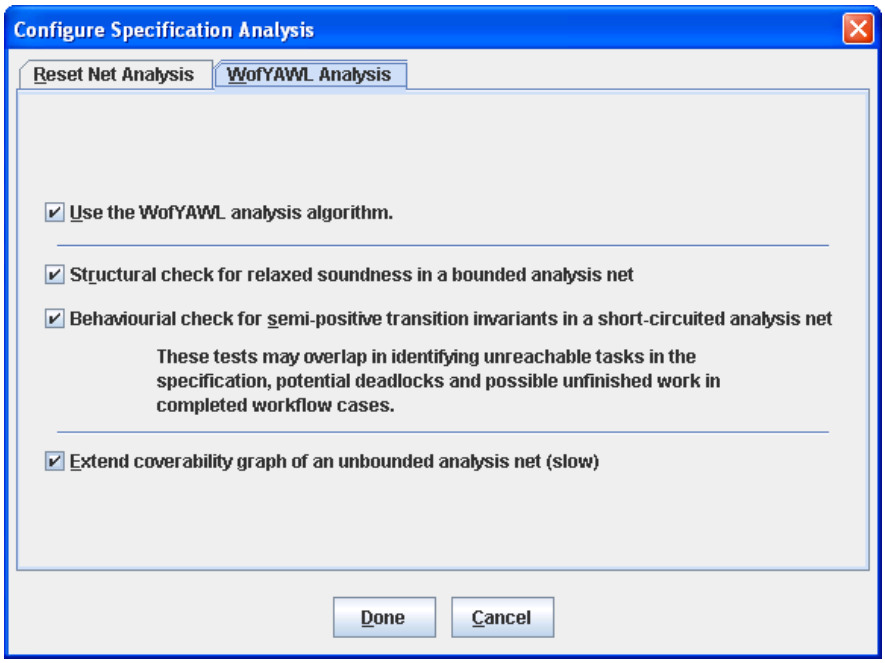

Configure Specification Analysis
Reset Net Analysis
WofYAWL Analysis
Use the WofYAWL analysis algorithm.
Structural check for relaxed soundness in a bounded analysis net
Behaviourial check for semi-positive transition invariants in a short-circuited analysis net
These tests may overlap in identifying unreachable tasks in the specification, potential deadlocks and possible unfinished work in completed workflow cases.
Extend coverability graph of an unbounded analysis net (slow)
Done
Cancel

Figure 4.52: Verification using wofYAWL

4.9 Task Documentation

A task may be annotated with descriptive text that will be viewable on a user's worklist at runtime. This text, or *documentation*, can be used to describe details about each instance of a task.

To add documentation to a task, right click on the task then select 'Set Documentation' from the context menu. A dialog will appear into which the text can be added (Figure 4.53).

XQueries that reference net-level variables can be embedded in the text, and are evaluated at runtime when the task is enabled. For example, the text in Figure 4.53 will resolve to "This claim has high priority" at runtime, assuming there is a net-level variable called 'priority' that has a value of 'high' when the task is enabled.

At runtime, the task documentation can be annotated on the fly so that, for example, messages can be passed from administrator's to user's regarding the task.

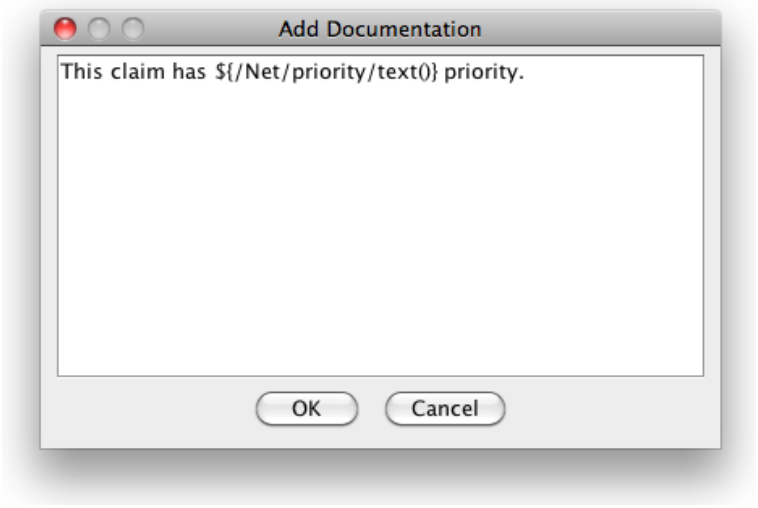


Figure 4.53: Set Task Documentation dialog

4.10 Automated task

Any atomic task in YAWL that is associated with the Resource Service (i.e. the default association if the task is not explicitly associated with another service) can have its decomposition defined as *manual* or *automated*. A task with a manual decomposition is a task that is intended to be executed by a human resource, e.g. a participant in the Resource Service's organisational model. A task with an automated decomposition is a task that is not offered to any resource but is executed by the system. This type of task can be used to manipulate the content of net variables, from simple data assignments to complex reports generation. Alternately it may be associated with a *codelet* – a discrete piece of code that is executed, optionally using the input variables of the task, and assigning any results to the chosen output variables of the task.

Both task types are handled by the Resource Service, but the behaviour of an automated task differs as follows:

- on enablement, it is automatically checked out of the engine (thus having priority over manual tasks in a deferred choice) and its input parameters are parsed;
- if a codelet has been specified, it will be executed it using the task's variables as required; then
- it is automatically checked in and its output variables are mapped back to the corresponding net variables.

A task is designated as manual by default, but can be set as automated by right-clicking on it and selecting the **Task Decomposition Detail** dialog, then ticking the **Automated** checkbox in the **External Interaction** section (see Figure 4.30). When the Automated checkbox is checked, the option **Manage Resourcing** in the task's right click menu will be disabled (since human resources are not required for automated tasks).

Data manipulation can be achieved by using the task's variables and their Input and Output Parameters. Parameters are generally used to copy the content of a net variable to a task variable and back again. But parameters may also contain an XQuery expression that uses static values, or the values of other variables, to copy data between net variables and task variables. Figure 4.54 shows an simple example of copying from expression, where the literal **true** is copied onto the net variable PO_timedout after choosing the from expression radio button. This choice is only available for automated tasks, and any task variables used in the XQuery expression itself must be declared as Input & Output usage types.

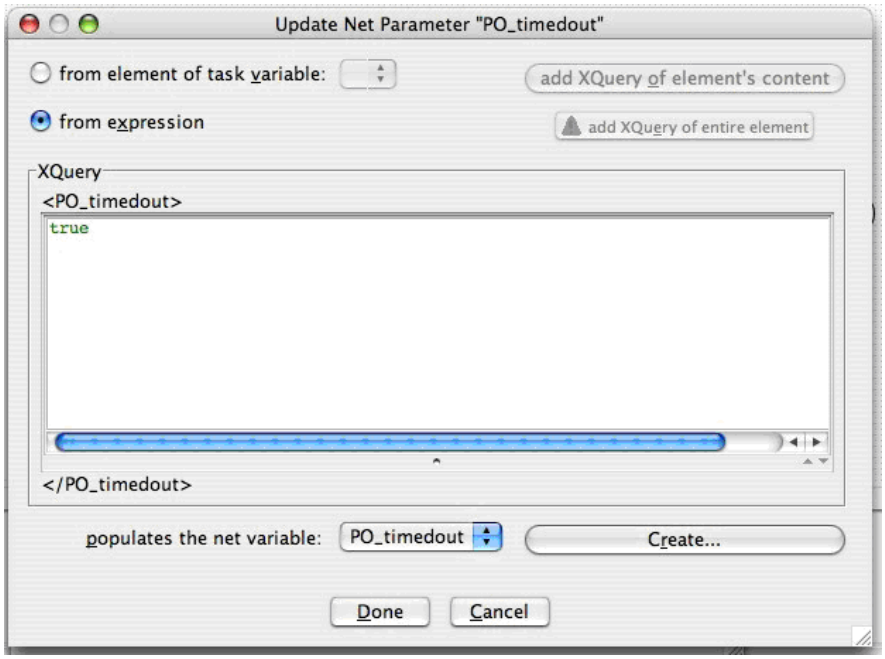


Figure 4.54: An output parameter set to copy from expression for an automated task

4.10.1 Codelets

Essentially, a codelet is a discrete Java class, managed by the Resource Service, that may be enacted by an automated task at runtime. When an automated task is enabled during process execution, and it has a codelet associated with it, the input parameters of the task are passed to the codelet, it is executed, and any results are passed back to the task via its output parameters.

There are currently six codelets available by default in the Editor (additional codelets can be added using a pluggable interface; see the *YAWL Technical Manual* for directions on how to add user-defined codelets):

- ExampleCodelet: a simple example designed to demonstrate the usage of codelets;
- XQueryEvaluator: accepts an XQuery as an input parameter, evaluates it (using other input parameters as required by the XQuery), and produces the result to an output parameter.
- RandomWait: accepts a time unit parameter ('H', 'M' or 'S') and a maximum value (type 'long'), and waits for a random amount of time units between zero and the maximum value.
- ShellExecution: accepts an input parameter containing a command line of an external program, and runs it, waiting for it to complete and returning the result (if any) via an output parameter.
- SupervisorInfo: accepts the userid of a user and returns the userid of that user's supervisor (based on the installed organisational data model - see Chapter 6 for more information).
- TaskCompleterInfo: Gets the name and userid of the participant who completed a specified atomic task in the current case.

To associate a codelet with a task decomposition, first mark the decomposition as automated by ticking the **Automated** checkbox in the Task Decomposition dialog (see Figure 4.30). When checked, the **Set Codelet** button is enabled; clicking that button opens the *Set Codelet for Automated Decomposition* dialog, listing the available codelets (Figure 4.55). Note that a valid connection to the Resource Service is required for this list to be populated with codelets. The dialog lists the available codelets, together with a description of what each one does and the task variables required to successfully execute it. For example, if ExampleCodelet

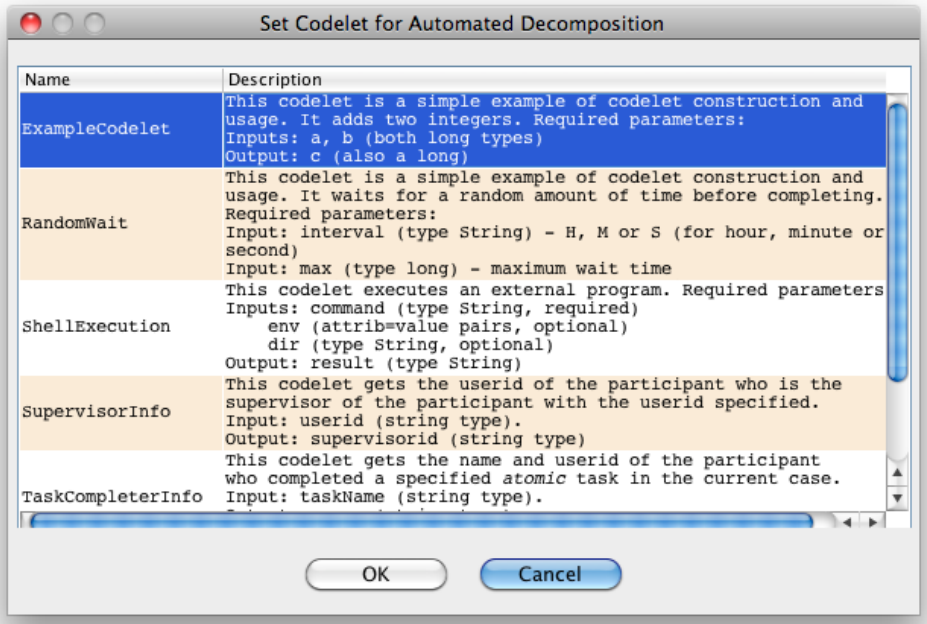

Set Codelet for Automated Decomposition
Name
Description
ExampleCodelet
This codelet is a simple example of codelet construction and usage. It adds two integers. Required parameters:
Inputs: a, b (both long types)
Output: c (also a long)
RandomWait
This codelet is a simple example of codelet construction and usage. It waits for a random amount of time before completing. Required parameters:
Input: interval (type String) - H, M or S (for hour, minute or second)
Input: max (type long) - maximum wait time
ShellExecution
This codelet executes an external program. Required parameters
Inputs: command (type String, required)
env (attrib=value pairs, optional)
dir (type String, optional)
Output: result (type String)
SupervisorInfo
This codelet gets the userid of the participant who is the supervisor of the participant with the userid specified.
Input: userid (string type).
Output: supervisorid (string type)
TaskCompleterInfo
This codelet gets the name and userid of the participant who completed a specified atomic task in the current case.
Input: taskName (string type).
OK
Cancel

Figure 4.55: The Set Codelet dialog

is chosen, the automated task requires 3 variables to be created: input parameters 'a' and 'b', and output variable 'c' (all of type 'long'). These parameters are automatically added to the task decomposition when the codelet is selected for a task – at runtime, if the required variables values are not present, the codelet will be unable to successfully complete (the task will still complete successfully, however).

The codelet repository has been designed as 'pluggable', so that designers and developers can easily add new codelets to perform various operations, which will immediately be available to process designers via the dialog above, as long as there is a valid connection to the Resource Service.

4.11 Resource Management (Manual task)

Once a connection with the Resource Service has been established, any manual atomic task with a decomposition (a task is manual by default, and only becomes automated when explicitly checked as automated in the Task Decomposition Dialog) can be allocated resources via a number of steps, by right-clicking on the task and selecting **Manage Resourcing**. This will launch the resource manager wizard.

A task may be allocated both human (i.e. a person) and non-human (e.g. rooms, vehicles, equipment, materials, etc.) resources. Further, resources are divided into primary and secondary resources. Primary resources are human resources that own a work list, so that allocating a work item to a primary resource means that work item will (potentially) appear on that resource's work list. Secondary resources consist of both human and non-human resources, and are those resources that are required to complete the work of task, but do not manage the task (as the primary resource does). Thus, each manually resourced work item, when executed, will have exactly one primary resource, and zero or more secondary resources.

To summarise:

- Human secondary resources don't see the work item on their work list.
- Non-human secondary resources don't have a worklist.

- A human resource may be a primary resource for some work items and a secondary resource for others.

- A non-human resource can never be a primary resource.

At runtime, when a work item is started, all of its allocated secondary resources (if any) are marked busy. When a work item is completed or cancelled, all of its busy secondary resources are released. All busy and release events are stored in the process logs. If a secondary resource is not available when a work item start is actioned, the work item may start anyway or may be blocked from starting, depending on a configuration setting (see Chapter 6 for more details).

Figure 4.56 shows the dialog window for Step 1 of the resource wizard.

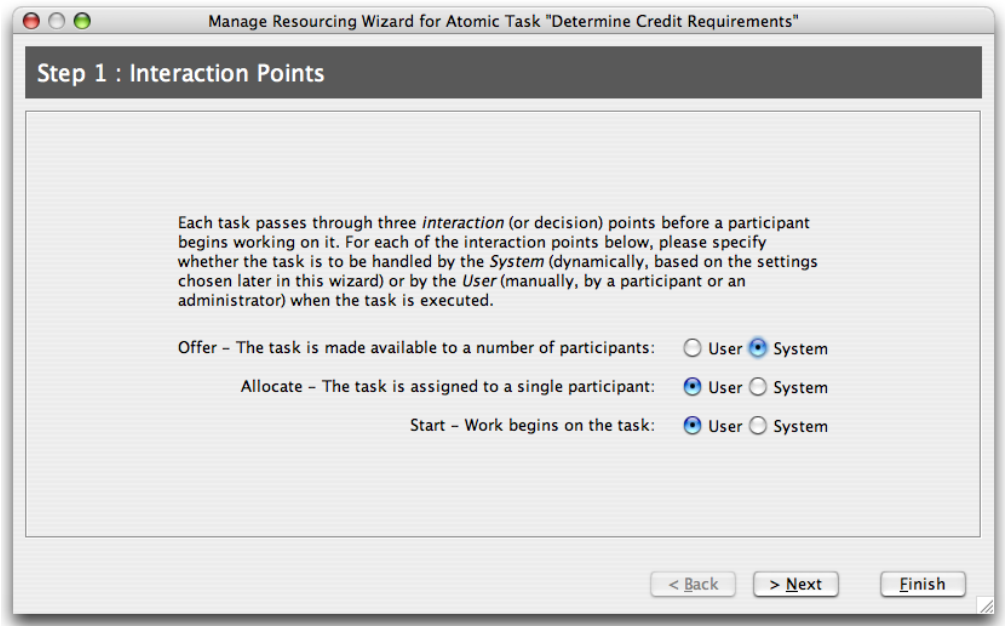

Manage Resourcing Wizard for Atomic Task "Determine Credit Requirements"
Step 1 : Interaction Points
Each task passes through three interaction (or decision) points before a participant begins working on it. For each of the interaction points below, please specify whether the task is to be handled by the System (dynamically, based on the settings chosen later in this wizard) or by the User (manually, by a participant or an administrator) when the task is executed.
Offer – The task is made available to a number of participants: User System
Allocate – The task is assigned to a single participant: User System
Start – Work begins on the task: User System
< Back
> Next
Finish

Figure 4.56: Step 1 of the resource management wizard

Step 1

In Step 1 we can specify the interaction strategy for work items of the selected task. There are three interaction points: offer, allocation, and start, each of which may be either User or System processed.

If we choose that work items are to be *Offered* by the User and not by the System, at runtime an Administrator will need to manually choose the resource(s) to offer the work item to. If System offering is chosen, then in Steps 2 and 3, we can specify the primary resources that will automatically be offered work items of the task at runtime.

If we choose that work items are to be *Allocated* by the User and not by the System, any participant who has been offered the work item can manually choose whether to commit to being responsible for the performance of the work item (i.e. to allocate the work item to themselves). If System allocation is chosen, in Step 5 we can specify how work items will be allocated to a participant by the System.

If we choose that work items are to be *Started* by the User and not by the System, then the user will choose to manually start working on the work item at a time of their choosing. If System starting is chosen, the work item, once it is allocated to the participant, will be immediately started.

Step 2

In Step 2, shown in Figure 4.57, we can select an initial set of primary resources (called the *distribution set*) that will be offered work items of the selected task at runtime by the System. The distribution set may consist of any number of participants and/or roles[4]. These can be picked from the relevant lists in this dialog (multiple selections are supported).

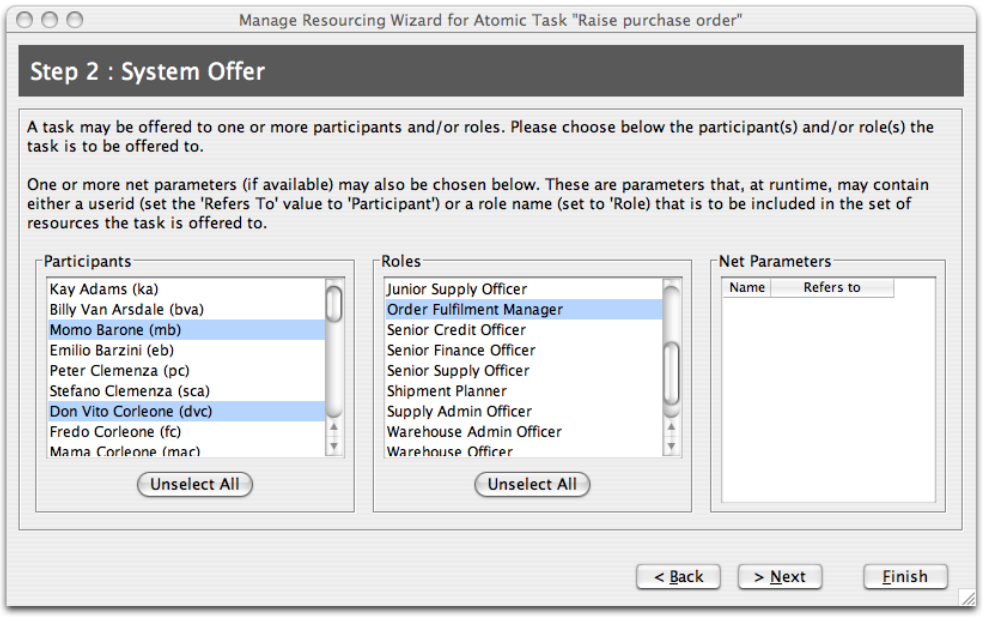

Manage Resourcing Wizard for Atomic Task "Raise purchase order"
Step 2 : System Offer
A task may be offered to one or more participants and/or roles. Please choose below the participant(s) and/or role(s) the task is to be offered to.
One or more net parameters (if available) may also be chosen below. These are parameters that, at runtime, may contain either a userid (set the 'Refers To' value to 'Participant') or a role name (set to 'Role') that is to be included in the set of resources the task is offered to.
Participants
Kay Adams (ka)
Billy Van Arsdale (bva)
Momo Barone (mb)
Emilio Barzini (eb)
Peter Clemenza (pc)
Stefano Clemenza (sca)
Don Vito Corleone (dvc)
Fredo Corleone (fc)
Mama Corleone (mac)
Unselect All
Roles
Junior Supply Officer
Order Fulfilment Manager
Senior Credit Officer
Senior Finance Officer
Senior Supply Officer
Shipment Planner
Supply Admin Officer
Warehouse Admin Officer
Warehouse Officer
Unselect All
Net Parameters
Name
Refers to
< Back
> Next
Finish

Figure 4.57: Step 2 of the resource management wizard

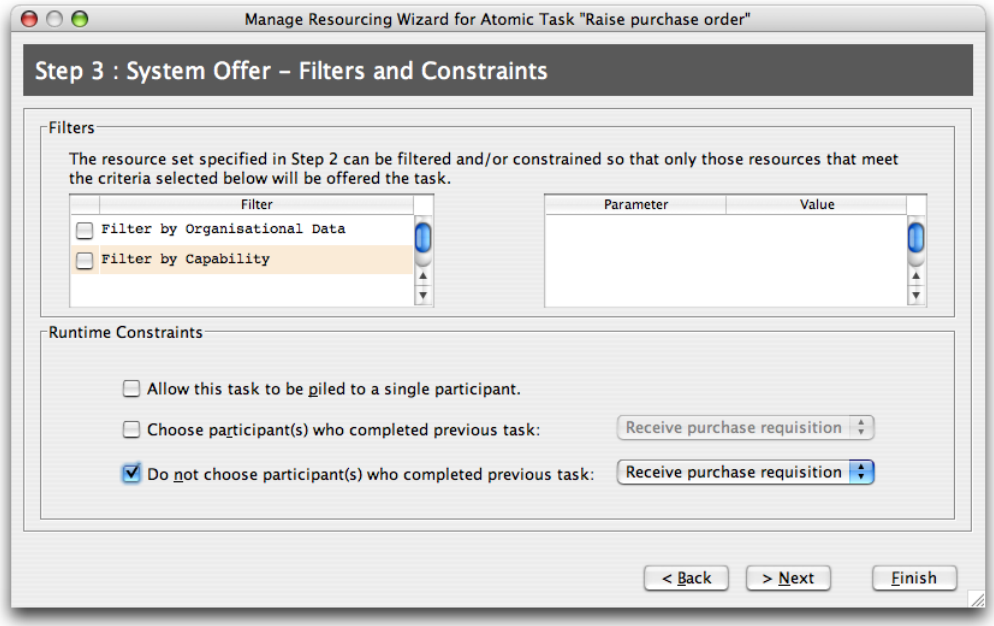

Manage Resourcing Wizard for Atomic Task "Raise purchase order"
Step 3 : System Offer – Filters and Constraints
Filters
The resource set specified in Step 2 can be filtered and/or constrained so that only those resources that meet the criteria selected below will be offered the task.
Filter
Filter by Organisational Data
Filter by Capability
Parameter
Value
Runtime Constraints
Allow this task to be piled to a single participant.
Choose participant(s) who completed previous task:
Receive purchase requisition
Do not choose participant(s) who completed previous task:
Receive purchase requisition
< Back
> Next
Finish

Figure 4.58: Step 3 of the resource management wizard

[4]A role is essentially a set of participants.

Additionally, in the Net Parameters panel you may nominate one or more net-level variables that at runtime will contain a value of the userid of a participant or the name of a role (that is, *deferred allocation*). For a variable to appear in the Net Parameters panel, it must be of type 'string' and usage 'Input & Output' or 'Input Only'. Note that *all* net-level variables that are of string type and have one of those usage types will be listed in the *Net Parameters* table, and will initially all be set as referring to 'Data'. For each of those that will contain resourcing information at runtime, the *Refers To* value must be changed to either 'Participant' or 'Role' via the drop down list on each row, depending on the type of resource the value will refer to at runtime.

Step 3

In Step 3, shown in Figure 4.58, we can filter the set of participants that have been described in Step 2. Filtering can be done over capabilities and/or over positions and organisational groups. Moreover, from this dialog it is possible to:

- allow the work items of the selected task to be offered only to participants who are members of the set specified in Step 2 and have previously completed work items of another task (as specified) in the current process instance;
- do *not* allow the work items of the selected task to be offered to participants who are members of the set specified in Step 2 and have previously completed work items of another task (as specified) in the current process instance;
- Allow all of the work items of the selected task to be *piled* to a particular participant, which means that, if a participant chooses to pile a work item of the task, that participant will be automatically allocated the work item *and all future instances of work items of the task for all future instances of the process containing the task*, until such time as piling is turned off for that task by the participant or an administrator.

Step 4

In Step 4, we choose the set of secondary resources that are required to successfully complete the task. Each item selected moves it to the list of 'Selected Resources' on the right hand side of the dialog. Individual participants and/or 'assets' (non-human resources) may be chosen at most once, while roles and categories (i.e. of non-human resources) may be selected more than once. For example, the selected resources in Figure 4.59 include two entries for the role 'Surgical Nurse', meaning that two nurses are required.

A category of non-human resources has a similar relation to that of a Role to participants – it is a grouping of resources. Each category also has listed a number of subcategories. For example, in Figure 4.59:

- *office machines* denotes any non-human resource in the office machines category, including all those listed in any subcategories.
- *office machines -> copiers* denotes those non-human resources in the 'copiers' subcategory of the office machines category.
- *office machines -> no category* denotes those non-human resources in the office machines category that are not further subcategorised.

If a participant chosen as a secondary resource also becomes the primary resource for a task, then its demarcation as primary resource takes precedence.

Step 5

In Step 5, shown in Figure 4.60, we can select the allocation mechanism that determines at runtime which participant, chosen from the members of the distribution set defined earlier, will actually be allocated the work item. The currently available mechanisms are:

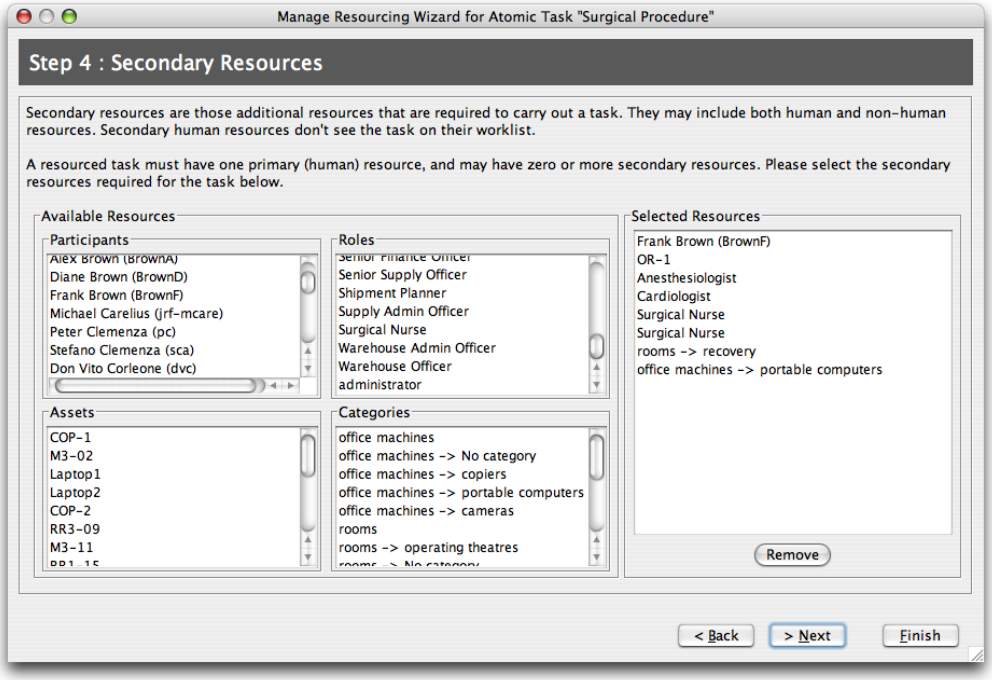


Figure 4.59: Step 4 of the resource management wizard

- Round Robin (by time): chooses the participant in the set who has not been allocated a task instance for the longest time;
- Round Robin (by least frequency): chooses the participant in the set who has been allocated this task instance the least number of times in the past;
- Round Robin (by experience): chooses the participant in the set who has been allocated this task instance the most number of times in the past;
- Random Choice: randomly chooses a participant from the set (the default); and
- Shortest Queue: chooses the participant in the set who has the least number of task instance currently in their work queue.

Step 6

In Step 6, shown in Figure 4.61, we can specify participant-task privileges (privileges that apply only for this task). For example, we can specify whether participants are allowed to suspend the execution of work items of the selected task.

More details on resource allocation and authorisation can be found in Chapter 6.

4.12 Task Timer

Any atomic task can be assigned a timer behaviour by right-clicking on it and selecting the **Set Task Timer...**. The dialog in Figure 4.62 will appear.

From this dialog it is possible to set an activation type and an expiration value for the timer. The timer can be activated either when a task is enabled (i.e. is offered or allocated) or when it starts. These have different meanings according to the type of task – manual vs. automated.

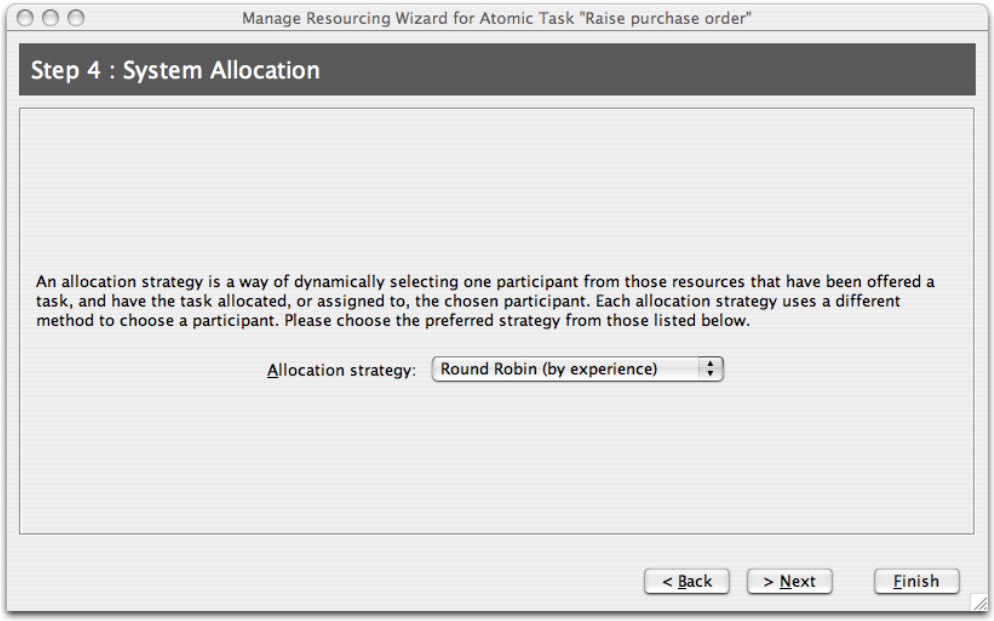

Manage Resourcing Wizard for Atomic Task "Raise purchase order"
Step 4 : System Allocation
An allocation strategy is a way of dynamically selecting one participant from those resources that have been offered a task, and have the task allocated, or assigned to, the chosen participant. Each allocation strategy uses a different method to choose a participant. Please choose the preferred strategy from those listed below.
Allocation strategy:
Round Robin (by experience)
< Back
> Next
Finish

Figure 4.60: Step 5 of the resource management wizard

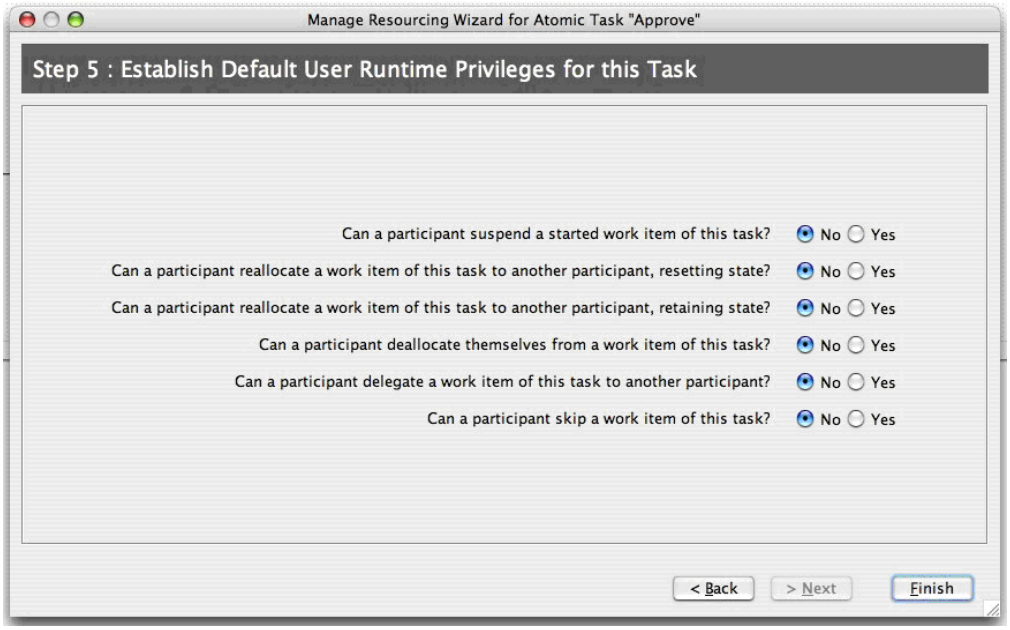

Manage Resourcing Wizard for Atomic Task "Approve"
Step 5 : Establish Default User Runtime Privileges for this Task
Can a participant suspend a started work item of this task?
Can a participant reallocate a work item of this task to another participant, resetting state?
Can a participant reallocate a work item of this task to another participant, retaining state?
Can a participant deallocate themselves from a work item of this task?
Can a participant delegate a work item of this task to another participant?
Can a participant skip a work item of this task?
No
Yes
< Back
> Next
Finish

Figure 4.61: Step 6 of the resource management wizard

4.12.1 Activation on enablement

- In the case of a manual task, as soon as the task is enabled, the timer begins and it remains live so long as the specified expiry time is not reached. During this time frame, the task will follow the normal resource assignment policy. In other words, it will be offered and can be allocated and started. Once the timer expires, the task instance will complete no matter what its current status is (offered, allocated, started). The possible danger of this behaviour is that a work item might be timed out while being edited by a user, in which case any modifications the user makes after that time are lost.

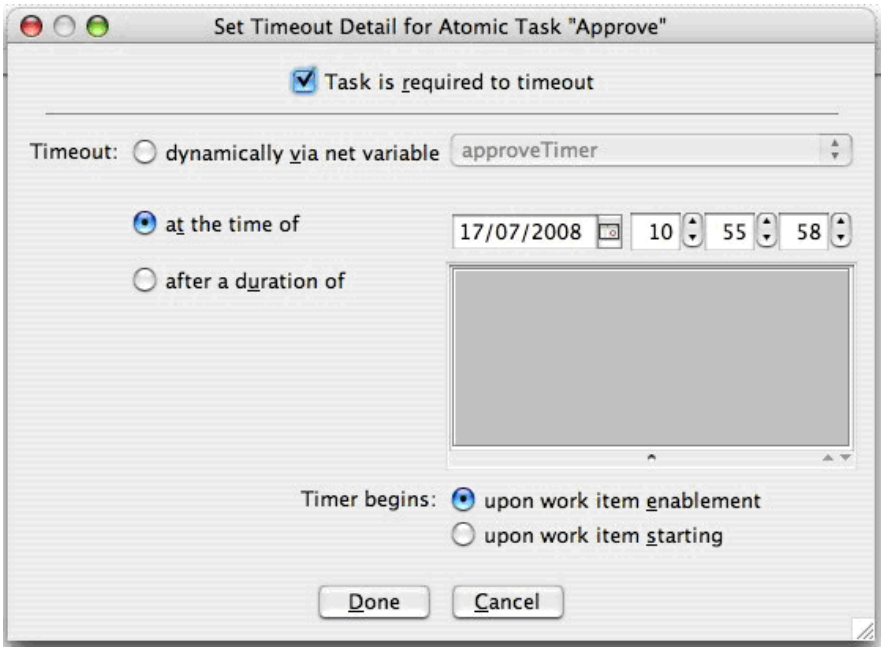


Figure 4.62: The timer dialog for an atomic task

- In the case of an automated task, the timer works as a delay, i.e. the automatic execution of the task instance created by an automated task is delayed until the specified expiry time is reached. Once the timer expires, the task is immediately executed and completed.

4.12.2 Activation on starting

- In case of a manual task, the timer begins only when the task has started. Therefore, the task will be first offered, then allocated, and once it is started the timer starts. Again, the timer may expire while the task is being edited by a user.
- This option is does not apply for an automated task.

4.12.3 Expiry value

The expiry value of the timer specifies for how long the timer will live after being activated. Expiry values can be expressed in either of two ways:

- Using a specific date and time, which means the timer will expire at the specified moment. To set a specific date and time, choose the 'at the time of' radio button on the Set Timeout Detail dialog (Figure 4.62) and enter the required values. Care should be taken when setting a specific time value for timers – if it happens that the specified value is earlier than the moment the task is actually enabled or started (depending on when it is set to activate), then the YAWL Engine will recognise that the timer has already expired and immediately complete the work item before it has a chance to appear on a worklist.
- Using a Duration value. A Duration is one of the built-in simple XML Schema data types, and is used to represent a period of time. When a Duration type is used as a timer expiry value, the timer will expire exactly when that period of time has passed since the work item was enabled or started (depending on when it is set to activate). To set a specific duration, choose the 'after a duration of' radio button on the Set Timeout Detail dialog (Figure 4.62) and enter the required value. A Duration value is expressed in the following form:

PnYnMnDTnHnMnS

All values start with P (for Period) followed by a non-negative number of years, months, days, then T (for time), followed by a non-negative number of hours, minutes and seconds. The seconds value can have a decimal point and as many digits following the point as required (e.g. to specify fractions of a second). Any zero value parts can be omitted. Valid examples: P1Y4M3DT23H55M1.5S, P2M3D, PT10S. Care should be taken when specifying a duration, for example P2M may mean a different number of days depending on what month it is started in.

In addition to the methods described above, timer parameters may also be set at runtime via a declared variable of type YTimerType, so that values can be supplied and late-bound to a task's timer settings. To use this deferred approach:

1. Create a net-level parameter of type YTimerType.
2. Choose a task, right click on it and choose **Set Task Timer...** to open the Set Timeout Detail dialog (Figure 4.62), click the 'dynamically via net variable' option and select the net-level parameter created in Step 1.
3. Map the net-level parameter to another (previous) task in the flow, which will be used to capture the required values from a user at runtime. Those values will be used to set the timer parameters on the task selected in Step 2. The values requested are:
   - **Trigger**: when should the timer start? There are two valid trigger values, *OnEnabled* and *OnExecuting*.
   - **Expiry**: when should the timer expire? This value can be either a date string (for example 12/12/08), which will be interpreted as a specific moment, or as a Duration value, which will be interpreted as a period of time.

An example of how a variable of YTimerType appears in a dynamic form at runtime can be seen in Figure 4.63.

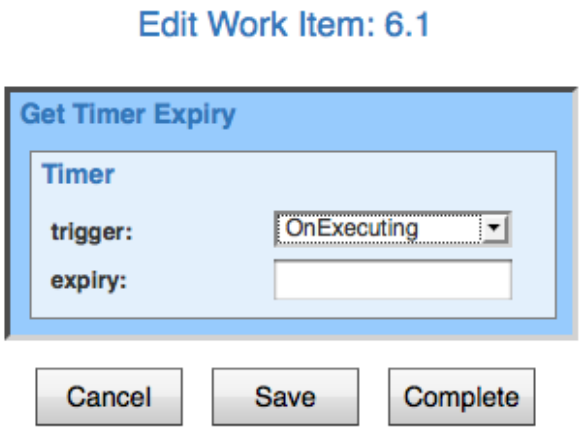


Figure 4.63: Example of a YTimerType variable rendered on a dynamic form

4.13 Custom Forms

When a task is associated with the default worklist handler (i.e. the Resource Service), then at runtime the data within the task instance may be selected for viewing and/or updating. By default, the Resource Service

uses a built in "dynamic forms" component, which generates appropriate but generic data editing forms designed for maximum flexibility and that can display data parameters of any type. However, their generic look and feel may not be appropriate in all cases, for example where an organisation has a standardised set of forms for their business processes, and would like their web-based forms to match that standard. In such cases, a *Custom Form* may be user-defined and associated with a task by specifying a URL to the form. At runtime for such a task, the Resource Service will package up the task data and send it to the custom form for display and/or editing (depending on how the form has been defined). On submission of the form by the user, the data is extracted from the form by the Service and passed back to the task in the same manner as dynamic forms. Custom forms may be built using any web-based technology, such as JSF, Javascript, .NET, PHP, or any other browser-based environment that can receive data, use it to populate form fields, update the data with user inputs, and pass control back to the calling service.

To set a custom form for a task, right click and select **Set Custom Form...**, then enter the absolute URI of the custom form (see Figure 4.64). To remove a custom form association, open the dialog and enter a blank URI (i.e. remove the URI from the dialog and click OK).

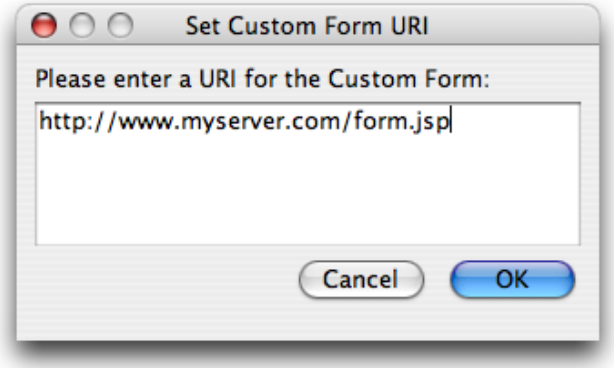


Figure 4.64: Custom form dialog

See the YAWL technical manual for information regarding the creation and configuration of custom forms.

4.14 Configurable YAWL

A configurable process model is an integrated representation of multiple variants of a same business process in a given domain, such as multiple variants of an insurance business process operating in different markets. A configurable process model offers the following benefits over traditional process models:

- eliminates redundancies in a process family,
- fosters standardization and reuse of proven practices,
- enables a clear distinction between commonalities (those parts that are shared by all process variants) and variants (those parts that are specific to certain process variants) in a process family,
- can be configured to meet specific requirements, such as those of a new organization, product or brand.

The YAWL Editor supports the definition of *configurable YAWL* (C-YAWL) models. A C-YAWL model is a YAWL model where some tasks are annotated as *configurable*. These configurable tasks represent the 'variable' parts of the process model, and are distinguished by a thicker border from the remaining tasks representing commonalities. Let's have a look at the example C-YAWL model in Figure 4.65. This model depicts a travel requisition process (you can find it in the YAWL distribution under the folder `C-YAWL models`). In this example, all tasks but the task labeled "tau" are configurable.

Configuration is achieved by restricting the behavior of a C-YAWL model. Configurable tasks can be restricted via the notion of *ports*. A configurable task's joining behavior is identified by one or more *input* ports, whereas its splitting behavior is identified by one or more *output* ports.

The number of ports for a configurable task depends on the task's routing behavior:

- AND-split, AND-join and OR-join are each identified by a single port.
- XOR-split and XOR-join are identified by one port for each outgoing/incoming flow.
- an OR-split is identified by a port for each combination of its outgoing flows.

For example, task "Submit Travel Form for Approval" has two input ports: one from task "tau", the other from task "Check and Update Travel Form", and three output ports: one towards task "Approve Travel Form Admin", one towards task "Reject Travel Form" and one towards task "Request for Change", while the latter task only has one input port and one output port.

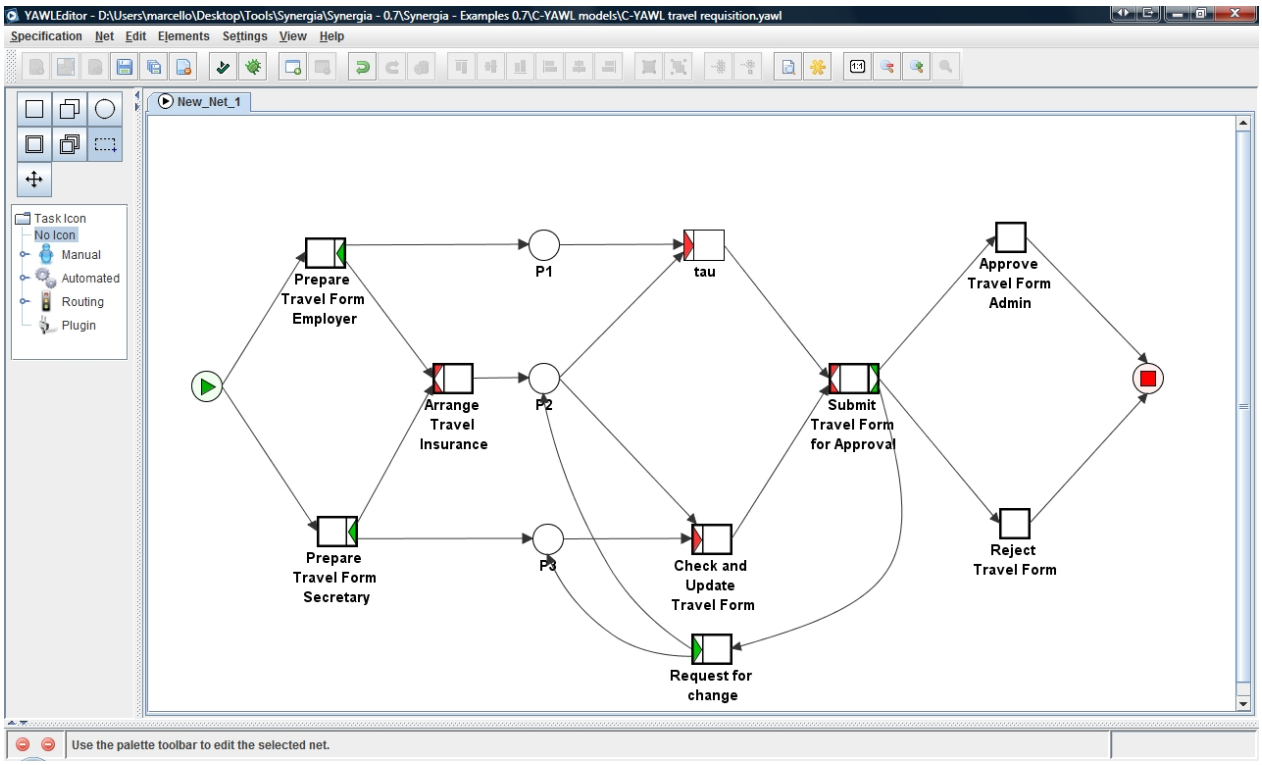


Figure 4.65: A C-YAWL model for travel requisition

To make a task configurable, you can right-click on it and select **Process Configuration** > **Set Task Configurable**. For example, let's make task "Submit Travel Form for Approval" configurable. Now we are ready to configure this task.

All ports are *activated* by default. You can configure them by either *blocking* or *hiding* them:

- Input ports can be hidden or blocked. Hiding an input port corresponds to making the task silent, i.e. the task will still be executed but its decomposition will be removed and thus the task won't have any observable behavior. Blocking an input port corresponds to inhibiting control to the task via that port, i.e. it will no longer be possible to execute the task via that port.
- Output ports can only be blocked. This means that the outgoing paths from that task via that port will be disabled.

Moreover, you can block the cancelation region assigned to a task (this means that the task's region will be removed altogether), and restrict the parameters of a multiple instance task. Specifically, you can reduce the maximum number of allowed instances, increase the minimal number of allowed instances and the continuation threshold, and change the dynamic creation of instances to static.

The configuration of input ports, output ports, cancelation regions and multiple instance parameters, can be accessed by right-clicking on a configurable task, and then selecting **Process Configuration** > **Input Ports...**, **Output Ports...**, etc. Figure 4.66 shows the dialog window for the output ports configuration of task "Submit Travel Form for Approval". You can select a single port or multiple ports by using the Shift or Ctrl keys, and then press the **Hide** or **Block** button to configure the selected ports, or **Activate** to rollback a configuration. It is also possible to set default configuration values for each port, by pressing the button **Set Defaults**. Once default configuration values have been assigned to a port, the button **Use Default** will become available when selecting that port, and you can configure that port by using its default value. All configuration settings (including default values) are stored in the YAWL specification upon saving, so this information will be preserved after closing the model.

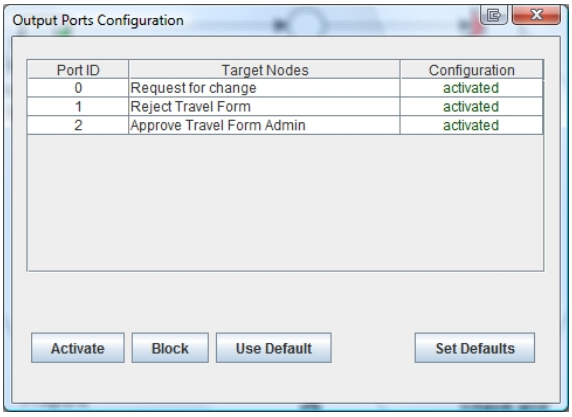


Figure 4.66: Configuring the input ports of a task.

Let's block the output port of task "Submit Travel Form for Approval" towards task "Request for change", and let's make task "Check and Update Travel Form" silent, by hiding its input port. With the first operation we deny requests for changes after a travel form has been submitted, by blocking the flow into the loop path, while with the second operation we deny the possibility of checking and updating a travel form, although in this case we don't block the flow through the hidden task.

The YAWL Editor can show a preview of the resulting configured net by graying out all model fragments which have been removed. You can do this by pressing the **Preview Process Configuration** button, , from the tool bar or from the menu **Net** > **Process Configuration**. Figure 4.67 shows the preview of the configuration in our running example. Task "Request for change" and its input and output arcs have been greyed out, whereas task "Check and Update Travel form" is still in the model (this task will actually be replaced with a silent task once the configuration has been committed). To remove a preview, simply press again on the respective button on the tool bar.

To commit a configuration you need to press the **Apply Process Configuration** button, , from the tool bar or from the menu **Net** > **Process Configuration**. This operation generates an *individualized* YAWL model, i.e. a regular YAWL model where:

- all blocked tasks and cancelation regions are removed,
- tasks attached to a hidden input port are replaced by a silent task bearing label "_tau",
- the parameters of all configurable multiple instance tasks are restricted according to the configuration settings,

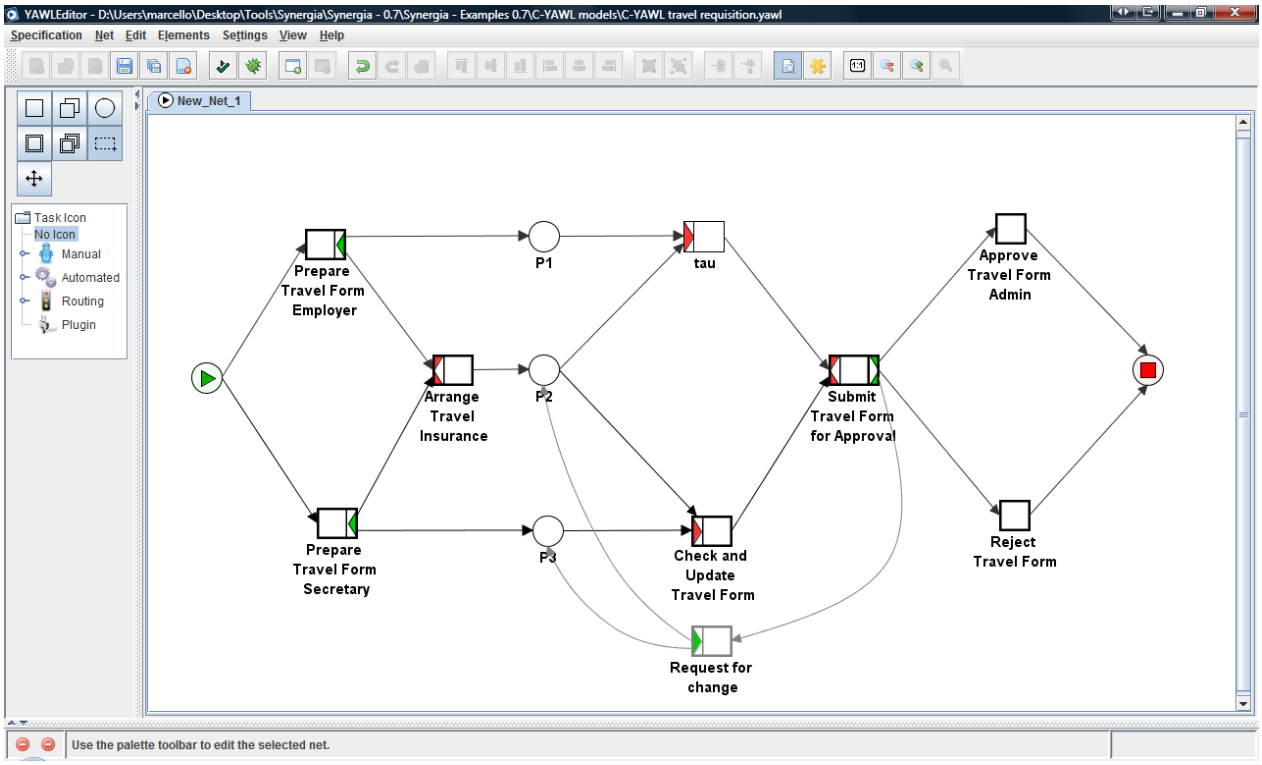


Figure 4.67: The preview of a process model configuration.

- all configurable tasks are turned into normal tasks.

Note that since a task can have multiple input ports (e.g. in the case of an XOR-join), those input ports that are not hidden will not be replaced with a silent task. For more information on how the configuration of hidden ports work, please refer to the Process Configuration book chapter of the YAWL Book [12].

Figure 4.68 shows the individualized YAWL model for the travel requisition example. Task "Request for change" and its connecting flows have been removed, whereas task "Check and Update Travel Form" has been replaced by a silent task labelled "_tau". If you inspect this task, you will see that it is no longer associated with a decomposition. Let's undo the commitment of this configuration to revert its effects. This can be done simply by pressing again the toggle button **Apply Process Configuration** on the tool bar.

While hiding a port is a safe operation, blocking a port may lead to behavioral anomalies such as deadlocks. If we now blocked the input port of the task "Check and Update Travel Form", we could cause a deadlock in condition "P3" because if task "Prepare Travel Form Secretary" fired, a token would remain stuck in that condition. So it would be wise to also block the input port of task "Prepare Travel Form Secretary", so that "P3" could never get control. The YAWL Editor provides a Configuration Correctness Checker which can be used to prevent possible behavioral issues already during configuration, by excluding those combinations of blocked ports that will lead to an unsound individualized YAWL model. In this way you don't need to individualize a process model to find out only later that the configuration you used led to an unsound model.

The Configuration Correctness Checker needs an external tool, namely Wendy [13], which must be located at the path specified in the menu item **Settings** > **External File Paths Settings**. There are Wendy distributions for Windows 32bit, MacOS and Linux available for download from the YAWL SourceForge project.

The Configuration Correctness Checker can be enabled at any time from the menu **Net** > **Process Configuration**. This will invoke Wendy to analyse the current model, and the output from this tool will appear in a pop-up window (see Figure **??**). This process may take some time depending on your machine's characteristics and on the degree of parallelism of your YAWL model (i.e. how many combinations of tasks there

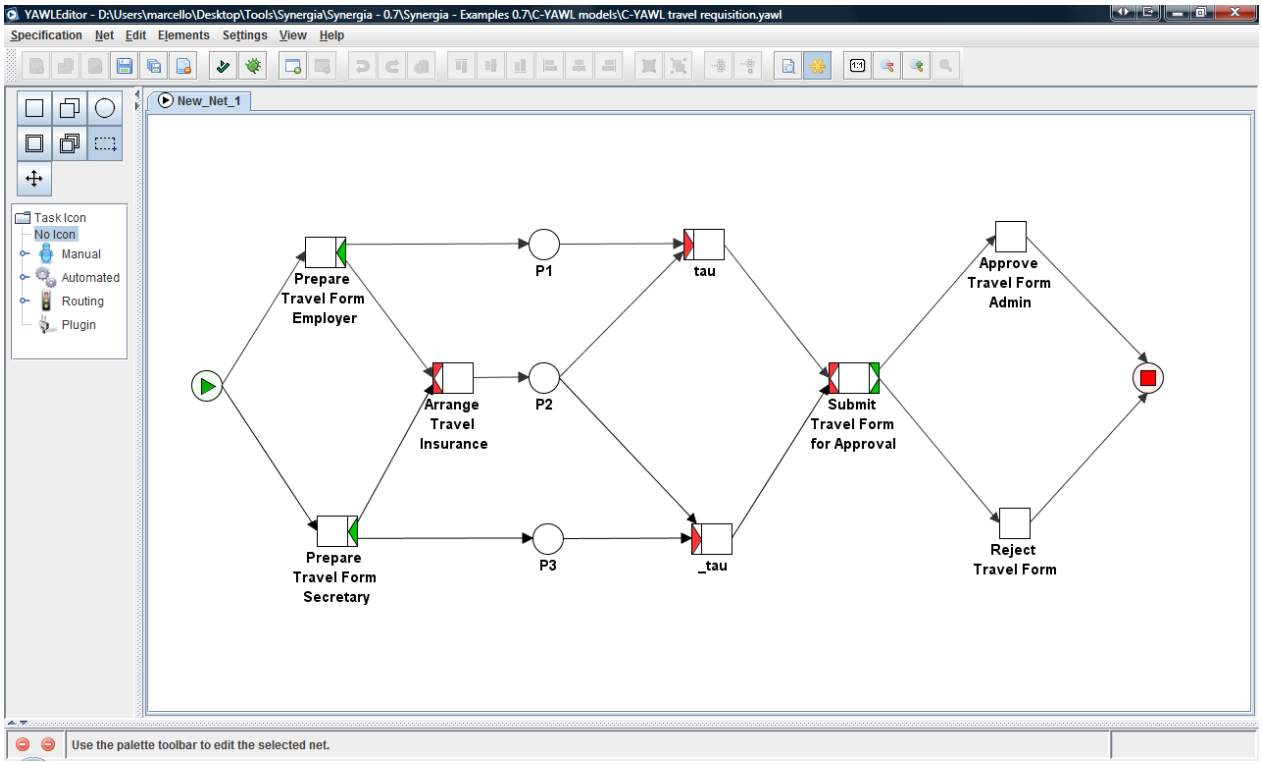


Figure 4.68: The result of committing a process model configuration.

exist that can be executed in interleaved parallelism). However you only have to run this process once, once you have completed the design of your process and are ready to configure it. You can also interrupt this process at any time by closing the window.

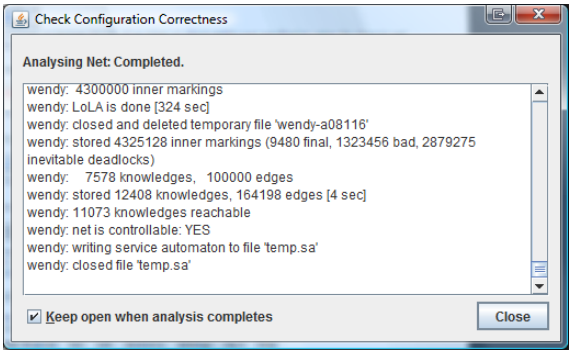

Check Configuration Correctness
Analysing Net: Completed.
wendy: 4300000 inner markings
wendy: LoLA is done [324 sec]
wendy: closed and deleted temporary file 'wendy-a08116'
wendy: stored 4325128 inner markings (9480 final, 1323456 bad, 2879275 inevitable deadlocks)
wendy: 7578 knowledges, 100000 edges
wendy: stored 12408 knowledges, 164198 edges [4 sec]
wendy: 11073 knowledges reachable
wendy: net is controllable: YES
wendy: writing service automaton to file 'temp.sa'
wendy: closed file 'temp.sa'
Keep open when analysis completes
Close

Figure 4.69: Output from Wendy.

Now launch the Configuration Correctness Checker for the travel requisition process. Once the analysis has been completed, the YAWL Editor will be able to automatically block or activate further ports in an interactive way, i.e. as you configure your model. Let's now block the input port of task "Check and Update Travel Form", which was previously just hidden. The Editor will react to that configuration by also blocking the input port of task "Prepare Travel Form Secretary", to avoid possible deadlocks in the individualized model. This is notified to the user via a dialog window (see Figure 4.70).

Figure 4.71 shows the preview of the resulting individualized model. You can see that condition "P3" will also be removed from the net now, as a result of applying this configuration.

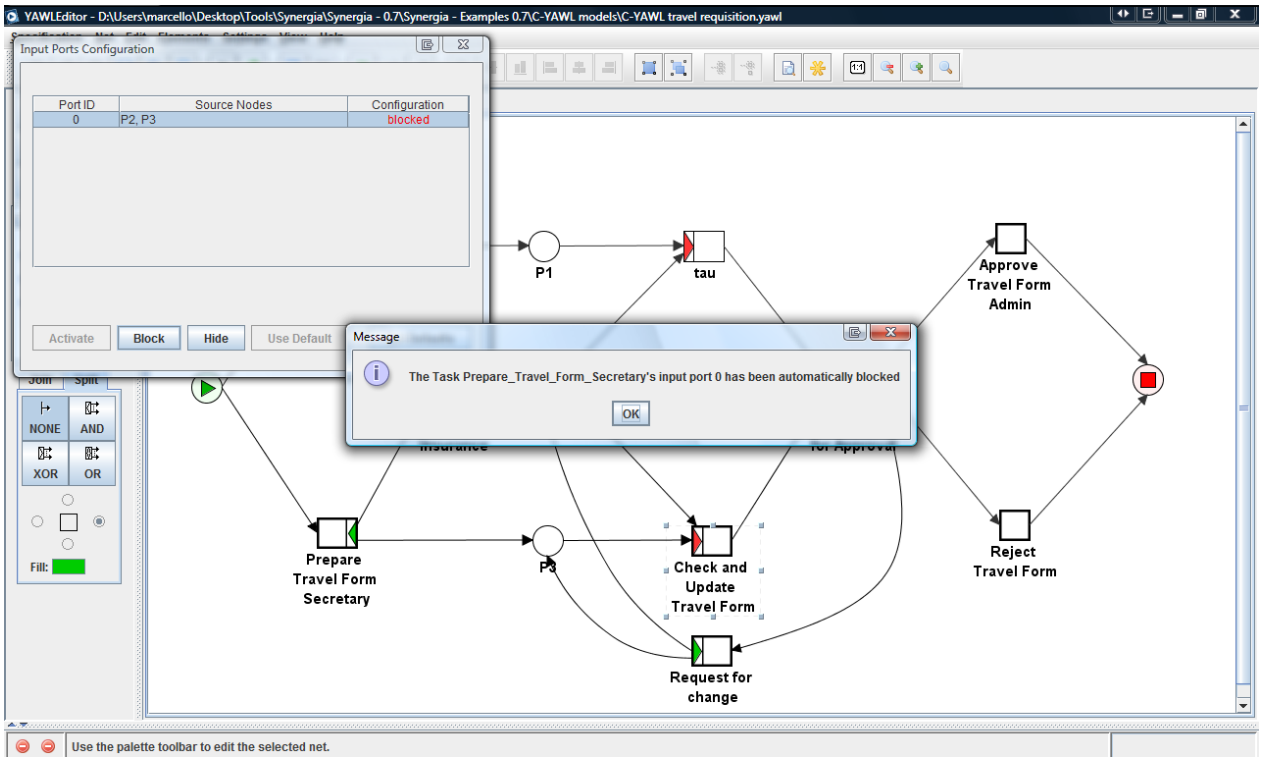


Figure 4.70: Notification of ports that are automatically blocked.

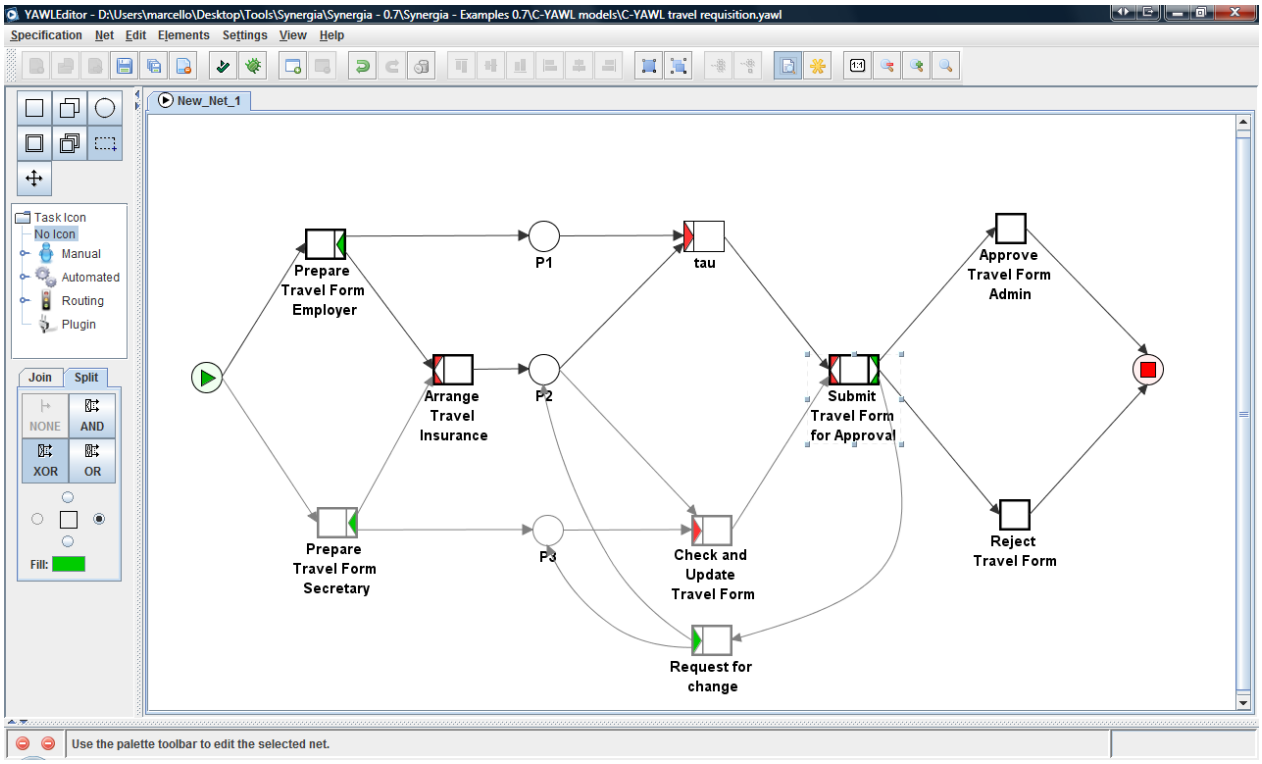


Figure 4.71: Preview of the configuration after blocking the input port of task "Check and Update Travel Form"

Automatic completion also works when you activate ports that were previously blocked. Try now to activate the input port of task "Prepare Travel Form Secretary". Since the input port of "Check and Update Travel Form" is blocked, a token may again get stuck in "P3"; so the Editor will also activate the latter port.

The following parameters related to C-YAWL models can be customized from the menu **Settings** > **Process Configuration Settings**:

- **Set new elements configurable**: new tasks are set as configurable automatically/manually (default option),
- **Preview process automatically**: the preview of configured processes is always switched on—the corresponding button on the tool bar becomes inactive/the preview can be switched on or off manually (default),
- **Deny blocking input ports**: input ports cannot be blocked/can be blocked (default),
- **Allow changing default configurations**: default configuration values can be changed (default)/cannot be changed.

For more information on C-YAWL, please refer to the Process Configuration book chapter of the YAWL Book [12] and go to www.processconfiguration.com. For technical details, you can also read the scientific paper [11].

4.15 Configurable Logging

The YAWL process logging framework keeps a record of all aspects of each process execution, including all control-flow, resourcing and data aspects, which can later be analysed. As part of the logging framework, provision is made for *configurable logging*, that is the ability to log messages (known as *Log Predicates* along with process data during process execution.

Log Predicates may be defined, for each process, that will be logged at the start and completion of each net, at the start and completion of each work item, and when data values are assigned to and from each net and task variable. A log predicate can contain any text, and may also contain *embedded values* describing current values for certain aspects of the process. Embedded values take the form **$**{***keyword***}, and different sets of values are available depending on whether the log predicate refers to a net, task or variable.

The available embedded values for a net-level log predicate can be seen in Table 4.2, while those at the task-level are listed in Table 4.3, and those at the variable-level are listed in Table 4.4.

${now}	Current date and time
${date}	Current date
${time}	Current time
${decomp:name}	Name of the net
${decomp:spec:name}	Name of the specification that contains the net
${decomp:inputs}	Names of any input parameters for the net
${decomp:outputs}	Names of any output parameters for the net
${decomp:doco}	Documentation supplied for the net
${decomp:attribute:*attribute_name*}	The value of the named extended attribute

Table 4.2: Available embedded values for net-level log predicates

If the resource service is handling the task, some extra embedded values become available for use within workitem level log predicates. The resource service will pre-parse the log predicate, replacing the embedded values it recognises with actual values, before passing the log predicate to the engine for final parsing of the workitem-level embedded values described above. The available embedded values for tasks handled by the resource service can be found in Table 4.5. Other custom services may also provide their own custom embedded values for log predicates – consult the documentation of custom services for details.

${now}	Current date and time
${date}	Current date
${time}	Current time
${spec:name}	Name of the specification containing this task
${spec:version}	Version of the specification containing this task
${spec:key}	Internal identifier of the specification containing this task
${task:id}	Runtime identifier of the task
${task:name}	Name of the task
${task:doco}	Documentation supplied for the task
${task:decomposition:name}	Name of the net that contains the task
${item:id}	Runtime identifier of the work item
${item:handlingservice:name}	Name of the service responsible for the work item
${item:handlingservice:uri}	URI of the service responsible for the work item
${item:handlingservice:doco}	Documentation supplied for the service responsible for the work item
${item:codelet}	Name of the codelet to be executed for the work item (if any)
${item:customform}	URI of the custom form to be displayed for the work item (if any)
${item:enabledtime}	Date and time the work item was enabled
${item:firedtime}	Date and time the work item was fired
${item:startedtime}	Date and time the work item was started
${item:status}	Current status of the work item
${item:timer:status}	Current status of timer set for the work item (if any)
${item:timer:expiry}	Expiration time of timer set for the work item (if any)
${item:attribute:*attribute_name*}	The value of the named extended attribute
${expression:*xquery_expression*}	The evaluated value of the XQuery expression specified. The expression may reference work item variable data values

Table 4.3: Available embedded values for work item-level log predicates

${now}	Current date and time
${date}	Current date
${time}	Current time
${parameter:name}	Name of the variable
${parameter:datatype}	Data type of the variable
${parameter:namespace}	Data schema namespace of the variable
${parameter:doco}	Documentation supplied for the variable
${parameter:usage}	Whether the variable is input, output or both
${parameter:ordering}	Index of the variable's order compared to the other task variables
${parameter:decomposition}	Name of the decomposition that contains the variable
${parameter:initialvalue}	Initial value of the variable (if any)
${parameter:defaultvalue}	Default value of the variable (if any)
${parameter:attribute:*attribute_name*}	The value of the named extended attribute

Table 4.4: Available embedded values for variable-level log predicates

${participant:name}	Name of the participant handling the work item
${participant:userid}	Userid of the participant handling the work item
${participant:offeredQueueSize}	Number of items in the handling participants offered queue
${participant:allocatedQueueSize}	Number of items in the handling participants allocated queue
${participant:startedQueueSize}	Number of items in the handling participants started queue
${participant:suspendedQueueSize}	Number of items in the handling participants suspended queue
${resource:initiator:offer}	Whether the workitem's offer interaction was initiated by the *system* or by a *user*
${resource:initiator:allocate}	Whether the workitem's allocate interaction was initiated by the *system* or by a *user*
${resource:initiator:start}	Whether the workitem's start interaction was initiated by the *system* or by a *user*
${resource:offerset}	A comma separated list of the names of all participants the workitem was offered to
${resource:piler}	The name of the participant piling the workitem (if any)
${resource:deallocators}	A comma separated list of the names of all participants who have deallocated the workitem
${resource:allocator}	Name of the system-based allocation algorithm used to allocate the workitem
${resource:roles}	A comma separated list of the names of all roles the workitem was offered to
${resource:dynParams}	A comma separated list of the names of all dynamic parameters used in the offer set evaluation for the workitem
${resource:filters}	A comma separated list of the names of all filters used in the offer set evaluation for the workitem
${resource:constraints}	A comma separated list of the names of all constraints used in the offer set evaluation for the workitem

Table 4.5: Additional resourcing embedded values for work item-level log predicates

Log predicates are optional, and so may be left empty if desired. To add a net-level log predicate, open the Update Net Decomposition dialog (via the menu **Net... Update Net Detail**), and click on the Log Predicate tab (Figure 4.72). To add a task-level log predicate, open the Update Task Decomposition dialog (right click on the task, then choose **Task Decomposition Detail...** from the popup menu), and click on the Log Predicate tab (Figure 4.73). To add a variable-level log predicate, open either of the previous two dialogs (depending on whether it is a net-level or task-level variable), then either create an new variable (via the **Create** button) or choose an existing variable from those listed and click the **Update** button, and click on the Log Predicate tab (Figure 4.74).

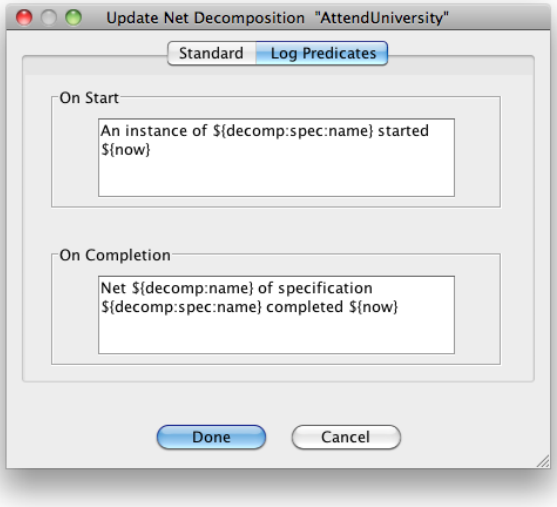


Figure 4.72: Entering net-level log predicates

4.16 Extended Attributes

The Editor offers a means for defining extended attributes to be associated with task decompositions and variables. There are a default set of attributes supplied for task decompositions, and a default set for task variables, the values of which may be set at design time; at runtime, the values (for the most part) will effect the display parameters of the dynamic form generated by the Resource Service's default worklist handler for the work item.

Additionally, designers may add their own extended attribute definitions to the Editor at design time, for runtime interpretation via custom classes and services. That is, the Resource Service will interpret and act on any values set for the default extended attributes, while the effects of values set for user-defined extended attributes are defined by developers of custom services. See Section 4.16.2 for information on defining your own extended attributes.

4.16.1 The Default Extended Attributes

Table 4.6 lists the default extended attributes for decompositions. For the most part, the attributes affect the work-item level of the dynamic form displayed (i.e the form itself). Note that where an variable-level attribute of the same name as a decomposition-level attribute exists, the variable-level attribute takes precedence.

Table 4.7 lists the default variable level extended attributes. For the most part, the attributes affect a single variable field on the dynamic form displayed.

Notes about extended attributes:

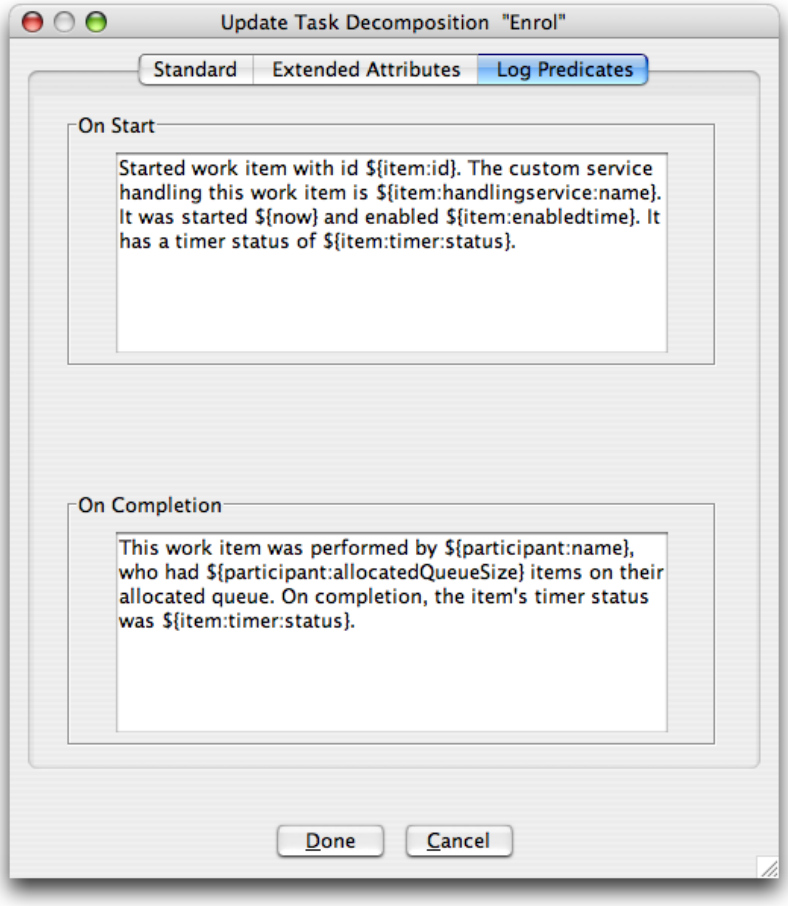

Update Task Decomposition "Enrol"
Standard
Extended Attributes
Log Predicates
On Start
Started work item with id ${item:id}. The custom service handling this work item is ${item:handlingservice:name}. It was started ${now} and enabled ${item:enabledtime}. It has a timer status of ${item:timer:status}.
On Completion
This work item was performed by ${participant:name}, who had ${participant:allocatedQueueSize} items on their allocated queue. On completion, the item's timer status was ${item:timer:status}.
Done
Cancel

Figure 4.73: Entering work item-level log predicates

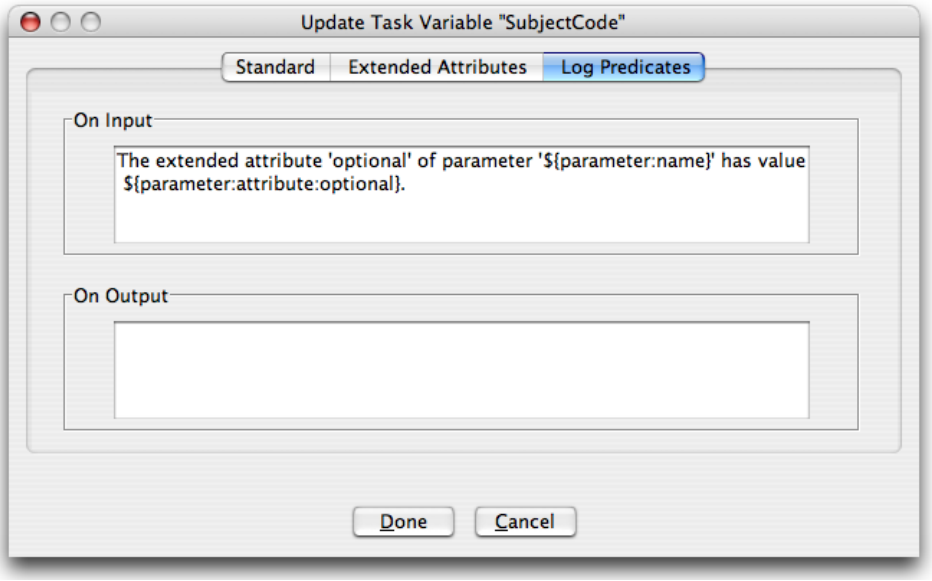


Figure 4.74: Entering variable-level log predicates

Attribute	Sets	Default
background-alt-color	The background color of alternating form panels	light blue (hex #D3E0FC)
background-color	The main background color of the form	blue (hex #97CBFD)
font-color	Font color for labels	black
font-family	Name of the font family used	browser default
font-size	Size of the font used	12 point
font-style	None, or Bold or Italic or both	None
header-font-color	Font color for headings	dark teal (hex #3277ba)
header-font-family	Name of the font family used for headings	browser default
header-font-size	Size of the font used for headings	14 point
header-font-style	None, or Bold or Italic or both	Bold
hideBanner	Suppress display of the YAWL banner, if true	false
justify	Justify text in text fields	left
label	Label text for form header	task name
page-background-color	The background color of the page	white
page-background-image	The background image url for the page	none
readOnly	Field values can't be modified, if true	false
title	Title of form	Edit Work Item: *item case id*

Table 4.6: Default decomposition-level extended attributes

- Those attributes marked with an asterisk (*) in Table 4.7 mirror XML Schema *facets* that may be set for values as part of the type definition for a field. If a extended attribute facet has a value, and the type definition also has a value for the facet, the extended attribute value takes precedence. Note that not all facets make sense for all data types – where a value is set for an extended attribute that mirrors a facet, and the field in question does not support that facet, then the value is ignored. For example, the facets minExclusive, minInclusive, maxExclusive and maxInclusive apply only to numeric fields. Please refer to an XML Schema reference for more information about facets and their application to different data types (for example, http://www.w3.org/TR/xmlschema-2/#rf-facets and http://www.w3schools.com/schema/schema_facets.asp).
- Values for the text-above, text-below and label attributes may include embedded XQuery/XPath expressions that reference the work item's data. See the Section 4.16.3 for examples.
- The readOnly attribute only applies to fields that would otherwise not be read-only. That is, a variable with usage type *Input Only* will display as read-only regardless of the value of the readOnly attribute, so the attribute will only apply to variables of usage types *Input & Output* or *Output Only*.
- For attributes that require a URL value, absolute URLs must be used. A simple solution is to create a subdirectory in the tomcat/webapps directory (called, for example, 'images') and place the images within it. Then, the absolute URL would be, for example, http://localhost:8080/images/myImage.png (assuming tomcat is installed locally).
- To avoid confusion, care should be taken when overriding the background color of a field, that the color used for validation errors (#FFCCCC), or colours close to it, are not used.
- A mechanism exists for extended attribute values to be set and/or modified at runtime – please see the Technical Manual for more information.

4.16.2 User-Defined Extended Attributes

User-defined extended attributes are specified in property files, one for decomposition-level attributes and one for variable-level attributes. By default, the Editor will look for attribute property files in the folder:

```
<editor_install_path>/YAWLEditorPlugins/ExtendedAttributeProperties
```

Attribute	Sets	Default
alert	A tailored validation error message	auto-generated message
background-color	The background color of the field	yellow (mandatory); white (optional)
blackout	Show field blacked out (unviewable), if true	false
font-color	Font color for the field & label	black
font-family	Name of the font family used	browser default
font-size	Size of the font used	12 point
font-style	None, or Bold or Italic or both	None
fractionDigits*	Number of digits to show after the decimal point	none
hide	Hide the field from view, if true	false
hideIf	Hide the field from view, if the XQuery value evaluates to true	false
image-above	URL for an image to show above the field	none
image-above-align	Alignment for image above the field	left
image-below	URL for an image to show below the field	none
image-below-align	Alignment for image below the field	left
justify	Justify text in the field	left
label	Text for the field label	variable name
length*	Exact number of characters required	undefined
line-above	Draw a horizontal line above the field, if true	false
line-below	Draw a horizontal line below the field, if true	false
maxExclusive*	One less than the upper range of valid values accepted	undefined
maxInclusive*	Upper range of the valid values accepted	undefined
maxLength*	Maximum number of characters required	undefined
minExclusive*	One more than the lower range of the valid values accepted	undefined
minInclusive*	Lower range of the valid values accepted	undefined
minLength*	Minimum number of characters required	undefined
optional	Field does not require a value, if true	false
pattern*	Field value must match the value pattern	undefined
readOnly	Field value can't be modified, if true	false
skipValidation	Don't validate value against schema, if true	false
text-above	Insert given text above the field	undefined
text-below	Insert given text below the field	undefined
text-area	Render a text area instead of a text field (text fields only)	
tooltip	A tip to show when the mouse hovers over the field	auto-generated tooltip
totalDigits*	Total number of digits expected (numeric values only)	undefined
whiteSpace*	Normalise whitespace in the given value	undefined

Table 4.7: Default variable-level extended attributes

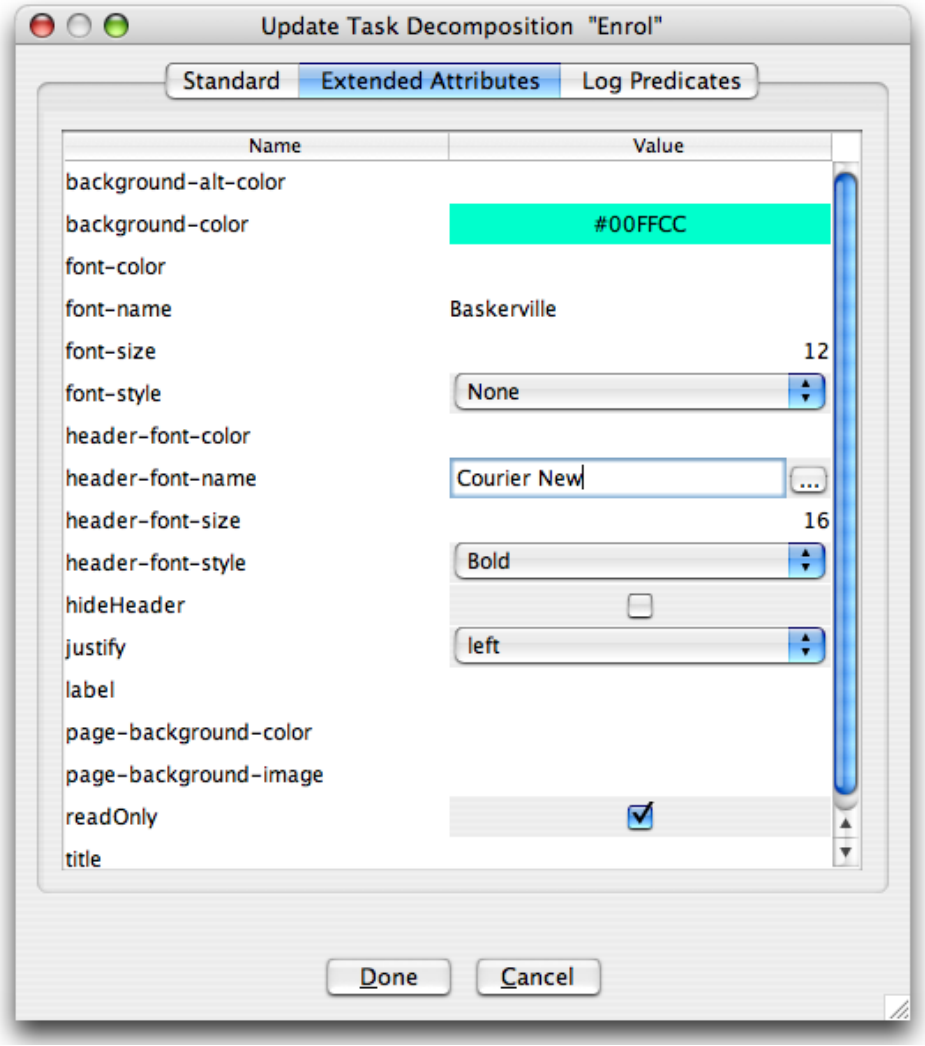


Figure 4.75: Default decomposition-level extended attributes

In that folder, the Editor will look for a file named DecompositionProperties (no extension) for decomposition-level properties, and a file named VariableProperties (no extension) for variable-level attributes.

However, the property files can be placed in any folder and use any filename – in that case, the location of the particular property file must be set in the External File Paths dialog (**Settings... External File Paths...**). The Editor will always look for the file in the last folder/filename set (or the default path/filename if never set).

Extended attributes are listed in the Update Task Decomposition dialog (see Figure 4.75 for an example with some values set) and the Update Task Variable dialog. The default attribute set is listed alphabetically in black text, while any user-defined attributes are listed alphabetically in blue text *below* the default set.

Attributes are defined as *key=value* pairs; the key represents the name of the attribute, and the value its type. The available attribute types are:

- **boolean**: may be given a value of true or false. Rendered as a checkbox in the Extended Attributes tab.
- **string**: a simple text string. Rendered as a text field.
- **color**: a color value. Renders as a text field with a hex RGB value.

- **font**: a valid font name. Renders as a text field.
- **integer**: a valid integer value. Renders as a text field. Invalid entries are ignored.
- **double**: a valid double value. Renders as a text field. Invalid entries are ignored.
- **enumeration**: a set of string or numeric values. Renders as a dropdown dialog.
- **xquery**: a valid XQuery expression.
- **text**: a long text value.

When the text field of an attribute with color, font, xquery or text type is selected, a small 'Open Dialog' button appears on the right-hand side of the field. When clicked, a dialog appropriate to the type will be displayed. Enter or select an appropriate value from the dialog, then click OK to save the value to the attribute. Figure 4.76 shows the dialog that appears for attributes of type *font*.

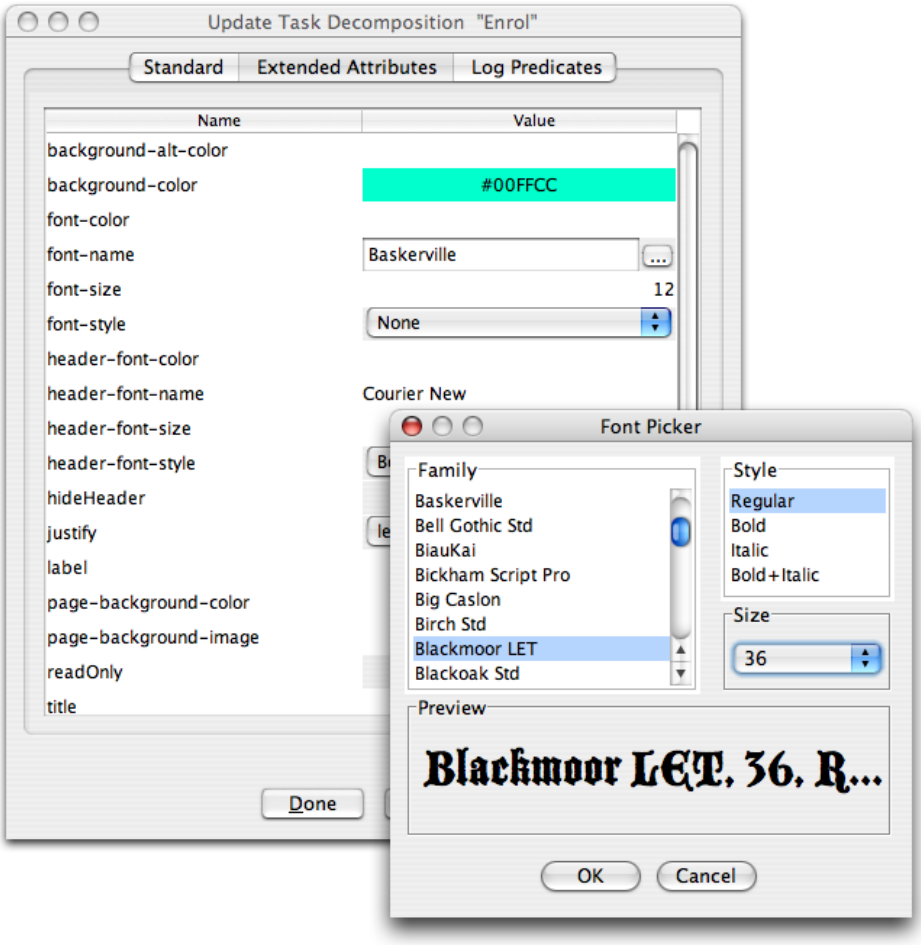


Figure 4.76: Extended attributes font type dialog

The following is an example of a property file that defines the attributes description, help, mode, refresh and showDetails (comments are indicated by a line starting with #).

```
#Decomposition Attributes
#Wed May 14 17:35:42 AET 2008
description=xquery
help=string
```

```
mode=enumeration{normal,final,pending}
refresh=xquery
showDetails=boolean
```

Only those values that are changed from their defaults will be saved to the specification file. For all types except *enumeration*, the default value is considered to be an empty field. For enumerations, the first listed value is considered the default. To denote an empty value as the first in an enumerated list, list the enumeration like this example (i.e with no first value):

```
mode=enumeration{,normal,final,pending}
```

Figure 4.77 shows the rendered list of attributes for the above property file (note that they are listed underneath the default attributes). Note that attributes can only be created through property files and not via the above dialogs.

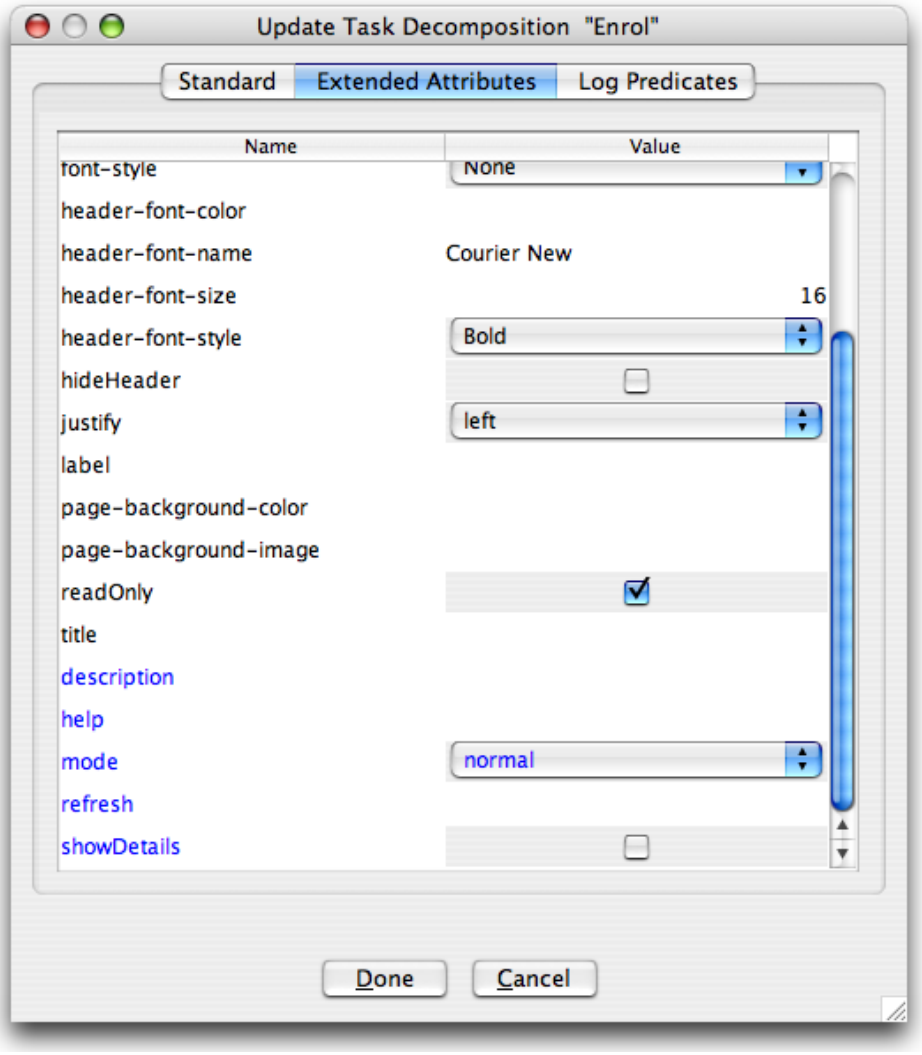


Figure 4.77: User-defined extended attributes displayed in the Extended Attributes tab

4.16.3 Extended Attribute Example

To show a small sample of what can be done with extended attributes, a simple specification called *EternalQuestion* will be used. The specification consists of two atomic tasks; the first requests an answer to the eternal question from a user, while the second shows the answer provided (in an Input Only variable). Figure 4.78 shows the process model, while Figure 4.79 shows how the dynamic form for the *Answer* task is displayed by default.

Figure 4.78: The EternalQuestion specification

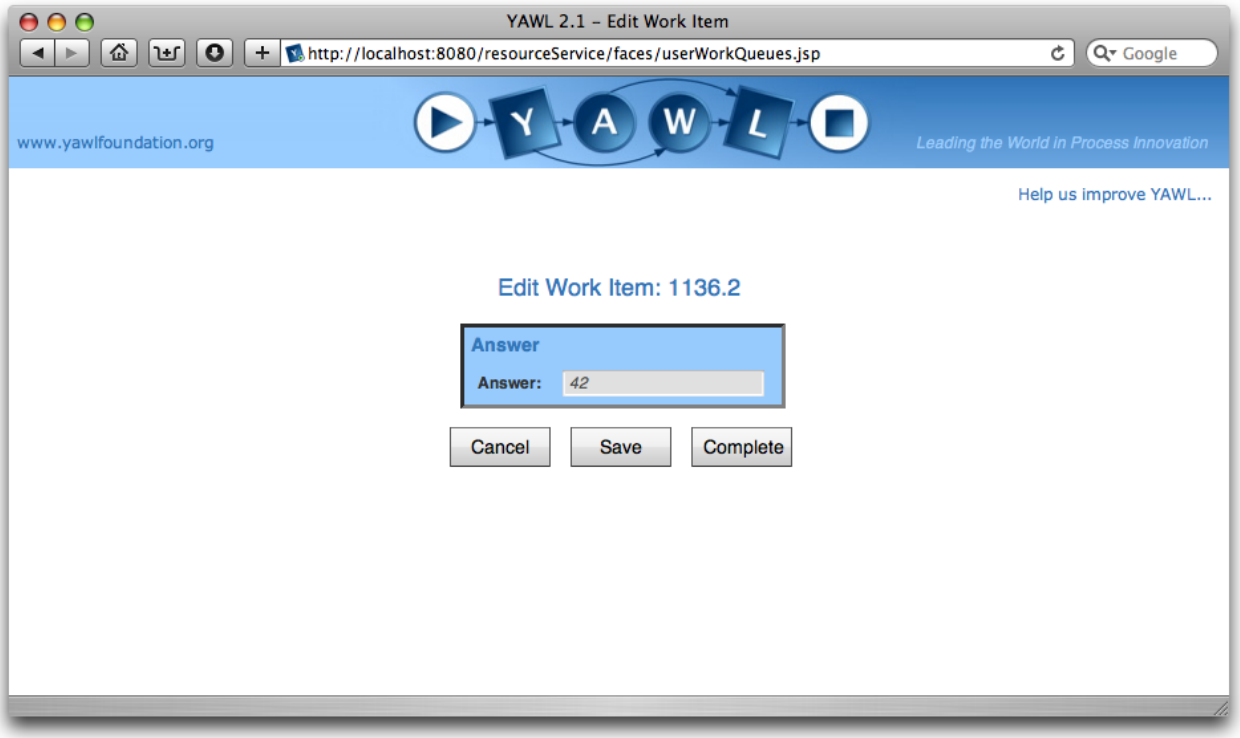


Figure 4.79: The default dynamic form for the Answer task

We would like to change the look of the form for the Answer task from the generic default to something more appropriate for this process, so values are provided for external attributes as follows:

- At the decomposition level:
  - **background-color**: white (#FFFFFF)
  - **page-background-image**: `http://localhost:8080/images/guide2.jpeg`
  - **hideBanner**: true
  - **title**: a space (to suppress the title display)
  - **label**: a space (to suppress the task-name label display)
- At the variable-level (the 'answer' variable):

- **font-family**: Capitals
- **font-size**: 20
- **font-color**: dark green (#009900)
- **image-above**: `http://localhost:8080/images/guide.jpeg`
- **image-above-align**: center
- **hide**: true (to suppress display of the text field)
- **text-below**: The answer to the meaning of life, the universe and everything is ${/Answer/answer/text()}

The effects of setting the attribute values listed can be seen in Figure 4.80. Remember that nothing has changed in the specification except for the setting of the extended attributes listed.

Notice that we have hidden the display of the field itself, because we have embedded the variable's value in the text-below attribute, via an XPath expression. This is a quite powerful construct, allowing usages like:

- "Total charge: ${number(/Order/subtotal/text()) + number(/Order/tax/text())}"
- "You ${if (number(/Exam/score/text()) > 50) then 'passed' else 'failed'} the exam!"
- "${if (boolean(/Question/response/text())) then 'Correct.' else 'Sorry, try again.'}" (assumes the response variable has a value of 'true' or 'false').

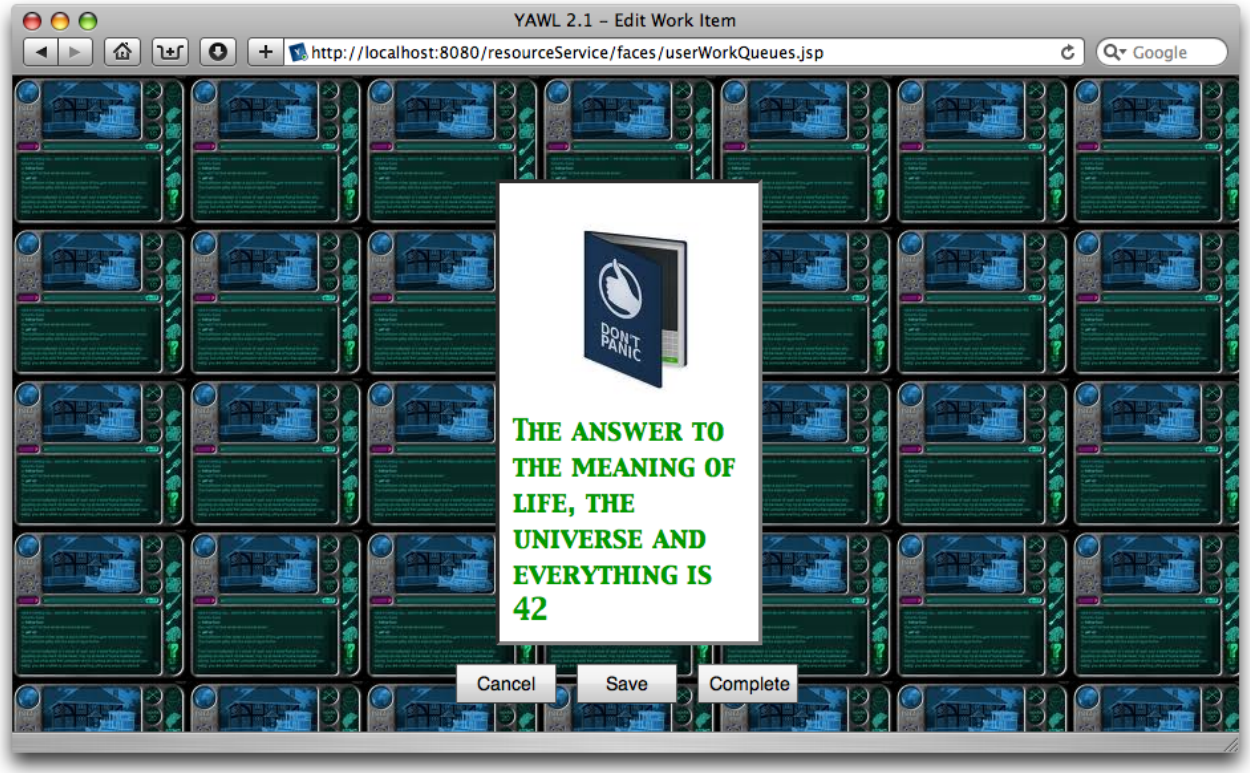


Figure 4.80: The dynamic form for the Answer task with certain extended attributes set

Editor Troubleshooting

The YAWL Editor is not responding to my mouse clicks and it is beeping every time I click the mouse.

Check to see if you have any Editor dialogs open. To do so, in Windows hold down the ALT key (for OSX, hold down the Command key) and press the TAB key until you reach the dialog window, then let go of the keys. Close the offending dialog window to re-enable use of the YAWL Editor.

I can't connect two elements with a flow. Why?

The Editor will not allow you to connect one element to another where such a connection is invalid. Typical examples include:

- Trying to connect a second flow to an undecorated task.
- Trying to point an incoming flow to a split decorator (or an outgoing flow from a join decorator).

See the troubleshooting entry "How do I find out more about elements and principles....." for more details.

When I validate my Net, I get the following validation message, 'The net (. . .) may complete without any generated work. Should all atomic tasks in the net be unlabelled?'

This message appears if none of your atomic tasks are associated with a decomposition. To add a decomposition to a task (and thus ensure that the engine will get a user to handle the task at this point in the workflow), right click on the task and choose **Select Task Decomposition...**. **Choose Create...** and in the following window, "Update Task Decomposition", and enter the name of your task under Decomposition Label, then click **Done**.

My specification won't validate without any errors and I don't know what to do.

First, check the logic of your specification and exercise every branch of your workflow for correctness.

If you are sure of your workflow, consult the YAWL website for the proper use of the YAWL elements:

http://yawlfoundation.org.

How do I find out more about the elements and principles of the YAWL workflow specifications?

For more information about the mechanics of the YAWL workflow elements, please consult the YAWL website:

http://yawlfoundation.org.

Chapter 5

How to Manipulate Data in YAWL

5.1 Introduction

Compared to most of the existing workflow management systems which use a propriety language for dealing with data, YAWL completely relies on XML-based standards like XPath[1] and XQuery[2] for data manipulation. This document provides some insights into data manipulation in YAWL, in terms of *data visibility* (defining data elements), *data transfer* (passing data between workflow components and exchanging information with the environment), data related issues such as *data-based conditional routing* and handling of *multiple instance data*. Readers are assumed to have knowledge of YAWL and its supporting tools: the YAWL engine (see Chapter 6) and the YAWL editor (see Chapter 4).

5.2 Data Visibility

In YAWL, all data are represented as XML documents. Figure 5.1 depicts an example of a YAWL net specifying a simple trip booking process. The data at the net level are written in an XML document with a root element named *PerformBooking* (i.e. the name of the net), while the data at the task level are written in an XML document for each task.

Next, data elements are stored in variables. There are: net variables for storing data that need to be accessed and/or updated by tasks in a net, and task variables for storing data that needs to be accessed and/or updated only within the context of individual execution instances of a task. Note that the task variables of a composite task are conceptually the net variables of the corresponding subnet.

YAWL applies strong data typing. Data types are defined using XML Schema. The YAWL Editor provides a list of all 46 XML Schema simple data types for variable definition. These include some basic types such as *boolean*, *string*, *double*, *decimal*, *long* (integer), *date* (in the format of *yyyy-mm-dd*) and *time* (*hh:mm:ss*). Based on the above, the users can also supply their own XML Schema to define more complex data types. Figure 5.2 shows the XML schema of a user-defined data type for element "CustInfo" which consists of both customer name and target start date for the booking trip process depicted in [6].

Data usage is also part of the variable definition. There are: *input and output* variables, *input only* or *output only* variables, and *local* variables. In general, data are written to input variables and read from output variables. Local data usage is applicable to net variables only. The local (net) variables are used to store data that can be manipulated only *internally* within the scope of the corresponding net.

Finally, a net variable may be assigned an initial value at design time. Further details will be given in the next section on data transfer.

[1] XML Path Language (XPath) 1.0. W3C Recommendation, 16 November 1999.
[2] XQuery 1.0: An XML Query Language. W3C Working Draft, 4 April 2005.

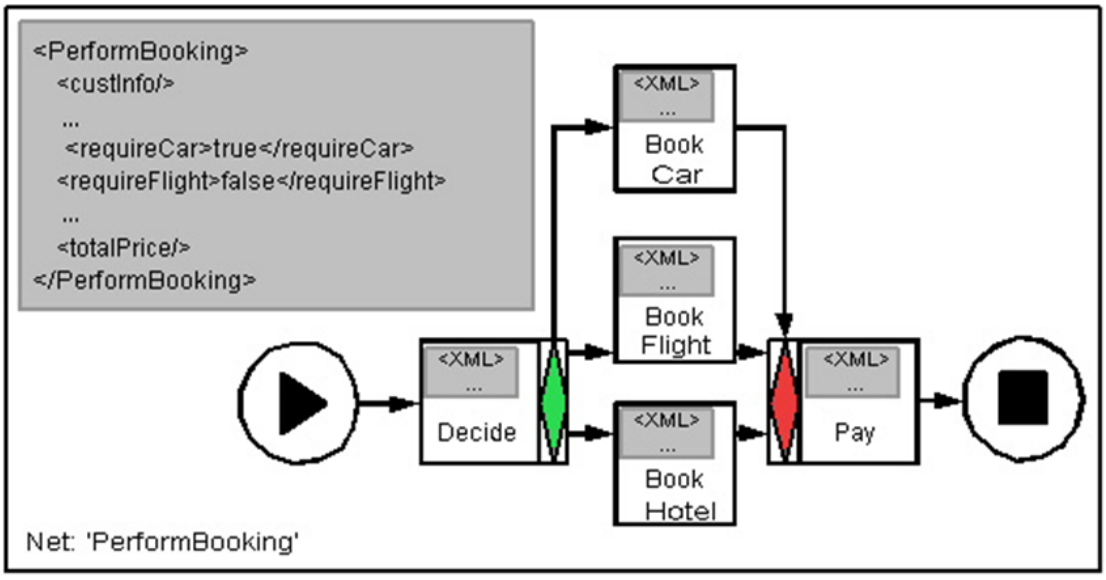


Figure 5.1: A YAWL net "PerformBooking" and its data representation

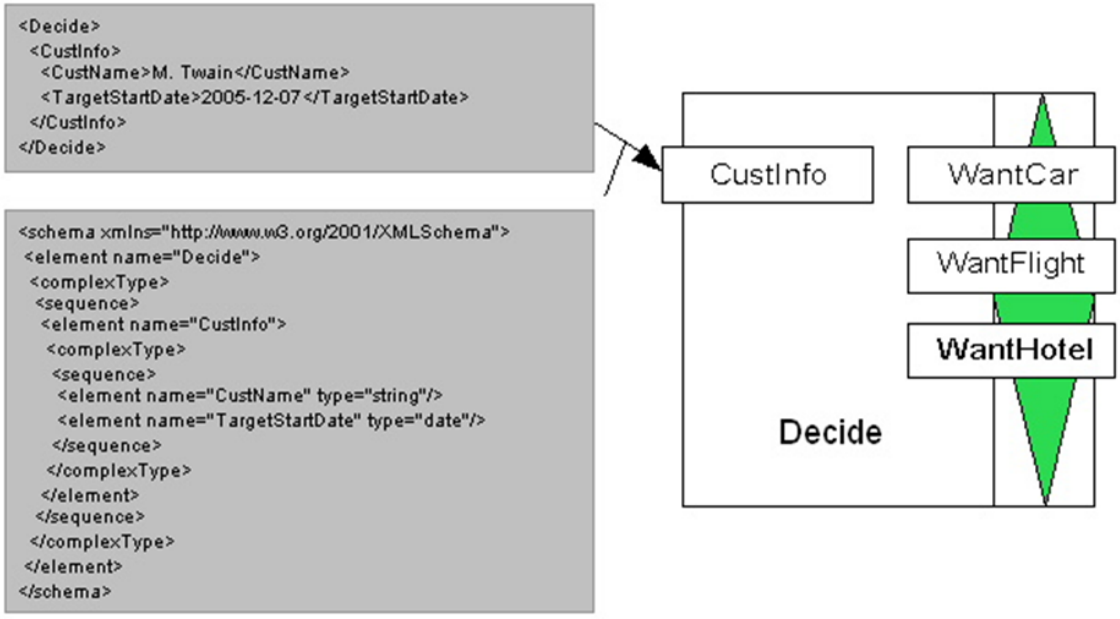


Figure 5.2: XML Schema of a user-defined data type for "CustInfo"

Note In Chapter 4, Section 4.5.3 to Section 4.5.6 illustrate how to define net and task variables in the YAWL Editor.

5.3 Data Transfer

5.3.1 Internal and External Data Transfers

YAWL supports data passing between variables, which can be considered internal data transfer, and data interaction between a process and its operating environment (i.e. workflow engine, users and web services), which can be considered external data transfer.

Internal data transfer is always conducted between nets and their tasks (which themselves may or may not be composite) using XQueries[3]. Note that YAWL does not support *direct* data passing between tasks. This is because each task variable is local to the task that the variable belongs to, i.e., it is not accessible by other tasks. Assume task A and task B in net N. To pass data from task A (e.g. variable Va) to task B (e.g. variable Vb), an appropriate net variable of N (e.g. Vn) must be available to convey data from Va to Vb. In the YAWL editor, each task can be assigned an *input parameter* and/or an *output parameter* (depending on the specified 'Usage' type) which define internal data transfer associated with that task. Input Parameters use an XQuery to extract the required information from a net variable and pass such information to the corresponding task variable, while output parameters define data passing in the opposite direction. Considering the process depicted in Figure 5.1, Figure 5.3 shows an example of passing the customer information from the net level to the task level (task "Decide").

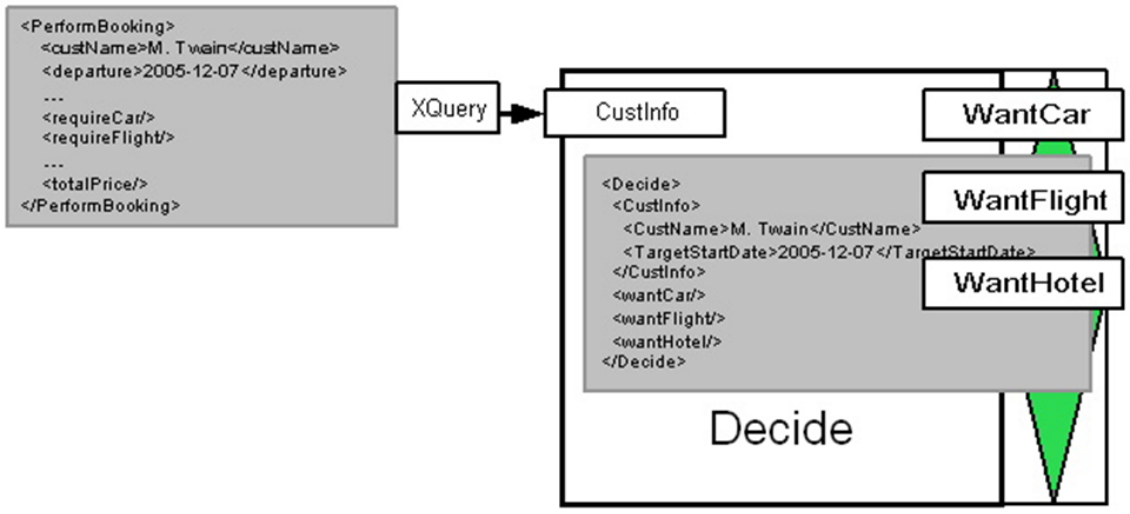


Figure 5.3: An example of data transfer from net "PerformBooking" to task "Decide"

External data transfer does not apply to any local variable or any variable of a composite task. This is because the local variables cannot be observed externally, and the variables of composite tasks serve as intermediate variables for passing data from the higher level to the lower level of a process and vice versa (e.g. between a net and the tasks in its subnets). When data are required from the external environment at run time, either a web form will be generated requesting the data from the user or a web service will be invoked that can provide the required data.

5.3.2 Valid and Invalid Data Transfers

To ensure correct data transfer, YAWL defines a set of transfer rules for variables of different data usage. Each input variable, except those associated with the top-level net (root net), must have data supplied from the corresponding net variables (which could be a single net variable or an aggregation of any number of net variables), via an input parameter definition. An input variable of the top-level net gets data supplied from

[3]XQuery 1.0: An XML Query Language. W3C Working Draft, 4 April 2005.

the environment (e.g. a user input) once an execution of the net is started; a local variable of the top-level net may be assigned an initial value at design time (data assignment). Each output variable, except those associated with composite tasks, requests data from the environment once the corresponding net or task is executed. An output variable associated with a composite task gets data via the net data in its subnet, using an output parameter definition. Otherwise, output variables are used to supply task data to corresponding net level variables (in internal data transfers).

Input and output variables combine usages. No (internal) data transfers are allowed to local variables of subnets and no (external) data transfers are allowed between local variables and the external environment.

Note In Chapter 4, Section 4.5.7 illustrates how to pass data between variables in the YAWL Editor. Three things are worth noting:

1. The YAWL Editor enforces correct data transfers between variables in the parameter definition for each task. For example, it is not possible to define data passing between local variables, or to set more than one input/output parameter on a single variable associated with a task.

2. In the YAWL editor, by running specification validation, a user can check whether or not required data transfers are missing. For example, if an input variable (V-in) of a task (T) does not have any data mapping specified, the validation result will indicate that "there exists an input parameter (V-in) in (task) T that is not mapped to by this task".

3. When specifying XQueries in the parameter definitions of a task, the YAWL editor may automatically generate an engine-compatible XQuery or indicate whether a user-defined XQuery has valid or invalid syntax (by displaying the query in green or red respectively). The semantics validation of XQueries is performed at run time by the YAWL engine. A semantic error may result in a *Schema Validation Problem* and the execution of the process may fail.

5.4 Data-related Issues

5.4.1 Data-based Conditional Routing

When tasks have XOR or OR splits, which branch to choose is determined by conditional expressions associated with flows. These conditions are boolean expressions that involve data within the process. The data may determine the evaluation results of the conditions and therefore influence the operation of the process.

In YAWL, the branching conditions are specified as XPath[4] boolean expressions in the *flow detail* for tasks with XOR or OR splits. The branches (flows) whose conditions (predicates) evaluate to true will be executed by the YAWL engine (all true branches for an OR split; the first true branch from an XOR split). Also, for each task with XOR or OR split, there is always a default flow that will be taken if none of the other flow predicates evaluate to true. We consider separately below tasks with XOR splits and the tasks with OR splits.

As an example, Figure 5.4 shows the XPath expression, which is specified at task "Decide", for choosing the branch of "Book Car" in the "PerformBooking" process depicted in Figure 5.1.

For a task with XOR split, all (conditional) flows are specified in a list, and their predicates are evaluated in the same order as they are present in the list. Since an XOR split allows only one flow to be chosen, once the engine reaches a flow predicate that evaluates to true, the corresponding flow will be chosen and the rest of the list will be not be evaluated. However, if the engine reaches the bottom of the list, the bottom-most flow will always be chosen as the default, and it is not necessary to evaluate the predicate associated with that flow. Therefore, the default flow of a task with XOR split is similar to the concept of an "otherwise" clause defined in most programming languages.

For a task with an OR split (e.g. the task "Decide" in Figure 5.4), all flows with their predicates are also present in a list. However, an OR split requires that all flows whose predicates evaluate to true are taken.

[4]XML Path Language (XPath) 1.0. W3C Recommendation, 16 November 1999.

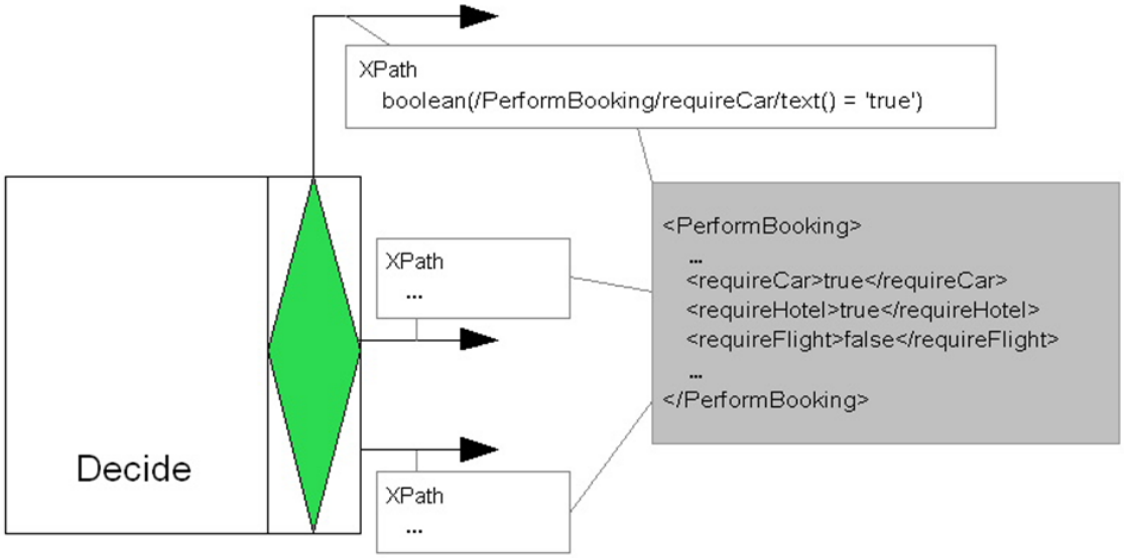


Figure 5.4: XPath expression for choosing the branch of "Book Car" at task "Decide"

Therefore, the engine will evaluate all flow predicates, and only if none of them evaluate to true will the bottom-most flow be taken as the default (despite the false evaluation result of its predicate).

Note In Chapter 4, Section 4.5.8 illustrates how to specify flow predicates for tasks with XOR or OR splits in the YAWL Editor. Two things are worth noting:

1. Only net variables are allowed to be used in specifying flow predicates. This is because the flow evaluation for a task with XOR or OR split is conducted after completing the execution of the task, and therefore the task variables are no longer available.

2. Similarly to the XQuery validation, the syntax validation of XPath expressions can be performed in the YAWL editor. The semantics validation is however a different matter. As YAWL applies only XPath boolean expressions for specifying flow detail, an XPath boolean expression with invalid semantics may evaluate to false, and as a result the execution of the process will still continue. In such a case, designers need to validate their YAWL specification against the desired system behaviour by themselves.

5.4.2 Multiple Instance Data

There are two categories of data associated with multiple instance tasks. One is the task attribute data which define the *maximum* and the *minimum* number of instances allowed as well as the *threshold* value. The other is the multiple instance data which are specific to individual execution instances of tasks within a single workflow case [20]. Below we describe how to handle multiple instance data in YAWL.

YAWL supports both the designated multiple instance tasks and the isolation of data elements between task instances. However, the handling of multiple instance data is far from trivial. Data at the higher level needs to be split over the instances and after completion of the instances aggregated to data elements at the higher level [2]. A set of four types of XQueries may be used to pass multiple instance data between different levels. These are: the *accessor query* for manipulating the overall multiple instance data before the unique values are split out (to individual execution instances); the *splitter query* for separating the unique values from the overall multiple instance data and passing a unique value to each instance; the *instance query* for transforming the XML document returned on completion of an instance to a form that is suitable

for aggregation; and the *aggregate query* for finally generating an overall result and passing the result to the higher level on completion of the multiple instance task.

In Chapter 4, Section 4.5.9 illustrates how to specify multiple instance data manipulation, e.g., the four types of XQueries, in the YAWL Editor.

5.5 Illustrative Examples

Below are three illustrative examples which cover the aforementioned data perspective of YAWL. The first example is a revised version of the "Credit Rating Process" taken from the "Oracle BPEL Process Manager: Quick Start Guide" (*10g Release 2*. May 2005). The next two examples are the first two "Make Trip Processes" that can be found in [2].

5.5.1 Example 1: Credit Rating Process

This is a simple process that provides a credit rating service. When running this process, the client (user) is asked to provide his/her social security number. The process takes the number and returns credit rating. There are two situations. If the client's social security number starts with 0, a fault reporting "Bankruptcy" will occur. Otherwise, a credit rating (e.g. 560) will be given. From the above, the data associated with this process are: 1) client's social security number (*ssn*), 2) credit *rating* (560), and 3) *fault* ("Bankruptcy").

YAWL Specification

Figure 5.5 shows the YAWL net specifying the above credit rating process. There are three labelled tasks: ReceiveSSN for requesting a social security number from the client; ReportFault for reporting a "Bankruptcy" fault; and DecideRating for providing the credit rating 560. There is also an unlabelled task, which has an XOR join; this is an example of a *routing* (or empty) task – that is a task without decomposition – and is used here to ensure the net is 'sound'.

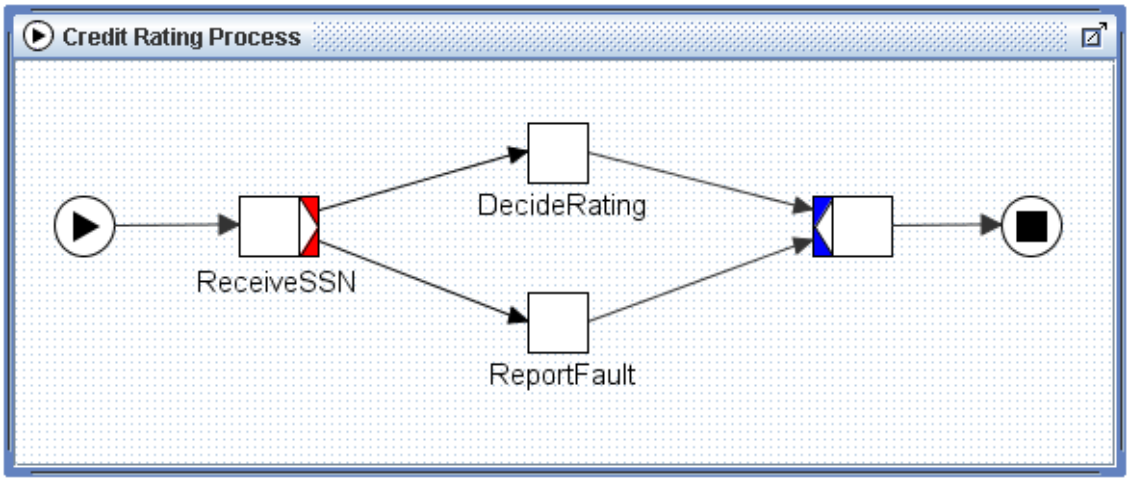


Figure 5.5: The "CreditRatingProcess" net

Figure 5.6 shows three net variable definitions for the "CreditRatingProcess" net. All are defined as local variables in order to avoid any data interaction with the external environment at the net level. Also, both *rating* and *fault* are assigned an initial value.

Figure 5.7 shows the parameter definition of task ReceiveSSN. It can be observed that this task has an output only variable called ssn. This variable requests social security number from the client, and as specified in the

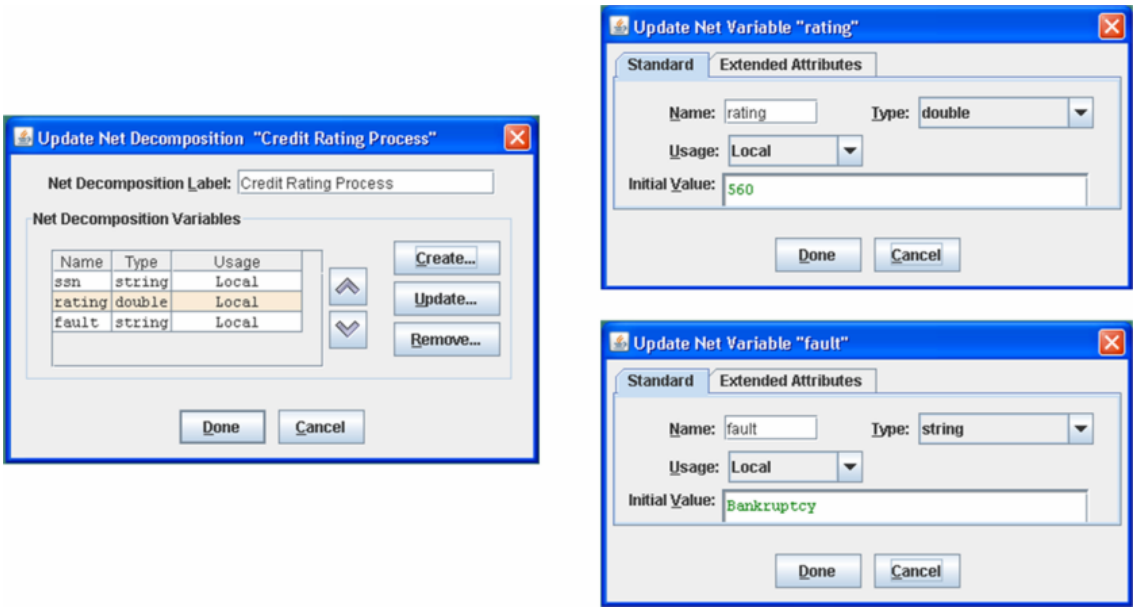


Figure 5.6: Net variable definitions

output parameter definition, it then passes the data to net via XQuery "{/ReceiveSSN/ssn/text()}", which can be generated automatically by clicking the **add XQuery of element's content** button in the *Update Net Parameter* dialog.

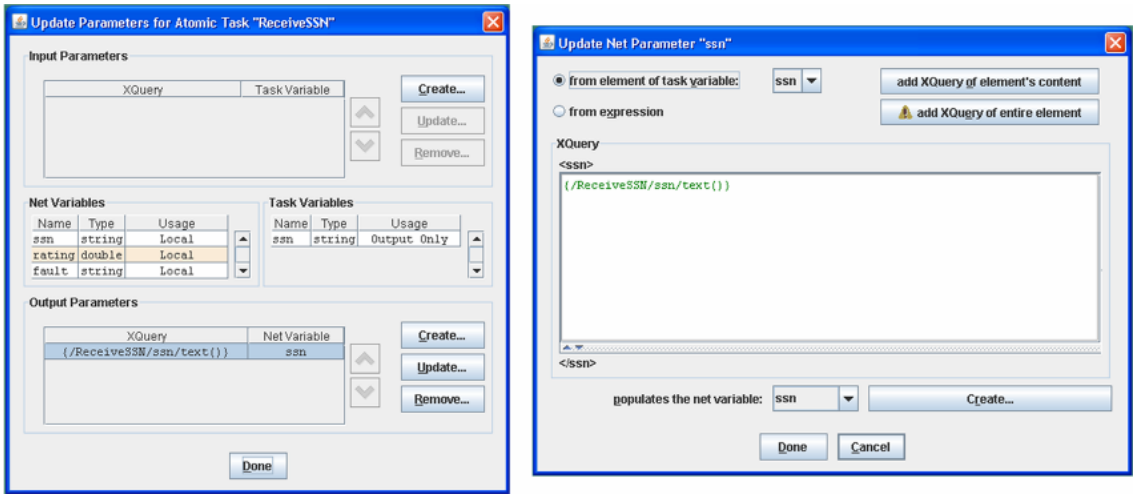


Figure 5.7: Parameter definition for task ReceiveSSN

Figure 5.8 shows the flow definition at task ReceiveSSN. The predicate for the flow leading to task ReportFault is "starts-with(/CreditRatingProcess/ssn/text(),'0')"[5]. It returns true if the string conveyed by variable ssn starts with zero. Otherwise, the flow leading to task DecideRating will be taken. Since the flow evaluation is performed from the top-most flow to bottom-most flow at run time, the bottom-most flow will be used as the default. The query "/CreditRatingProcess/ssn/text()" can be generated by clicking the **XPath Expression** button in the *Update Flow Predicate* dialog.

Figure 5.9 shows the parameter definition for task ReportFault. The variable *fault* is used to carry the fault

[5]**starts-with**(*string*, *string*) is an inbuilt XPath boolean function. It returns true if the first argument string starts with the second argument string, and otherwise returns false.

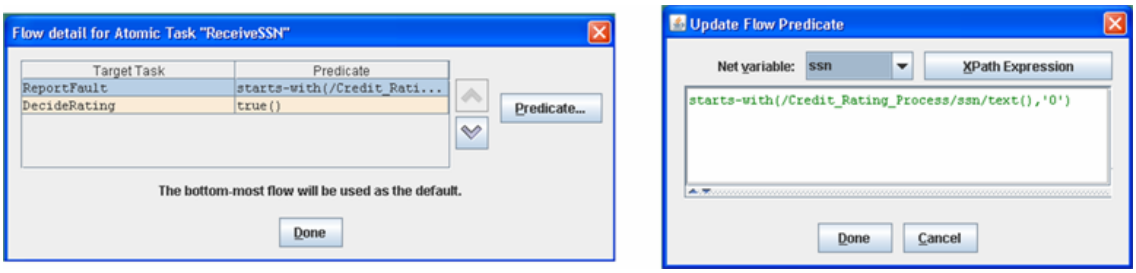


Figure 5.8: Flow definition at task Receive SSN

information ("Bankruptcy"). It is defined as input only because the fault information is only used for client notification upon execution of the task.

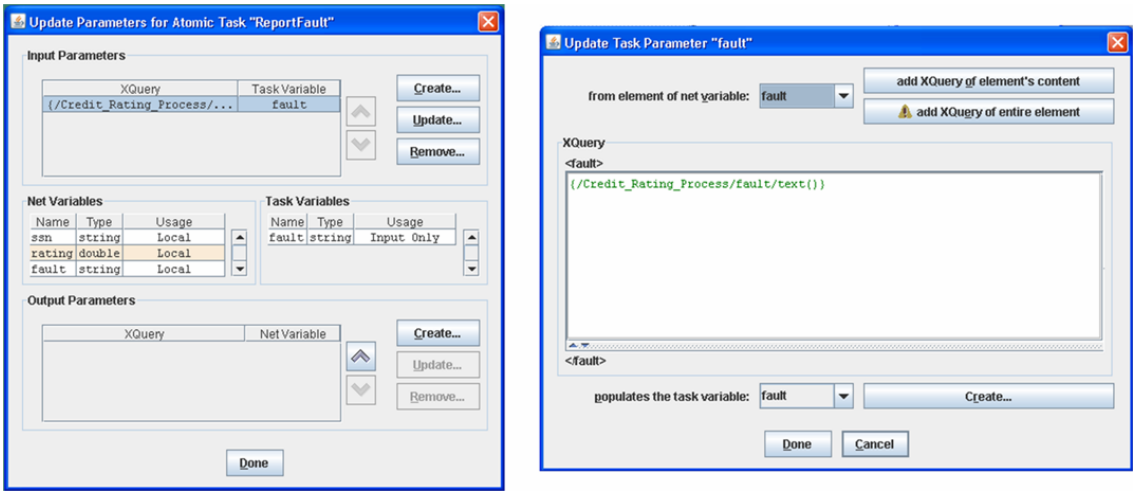


Figure 5.9: Parameter definition for task ReportFault

Figure 5.10 shows the parameter definition for task DecideRating. Similarly, the input only variable *rating* is defined to convey the credit rating (560) that is only used for client notification upon execution of the task.

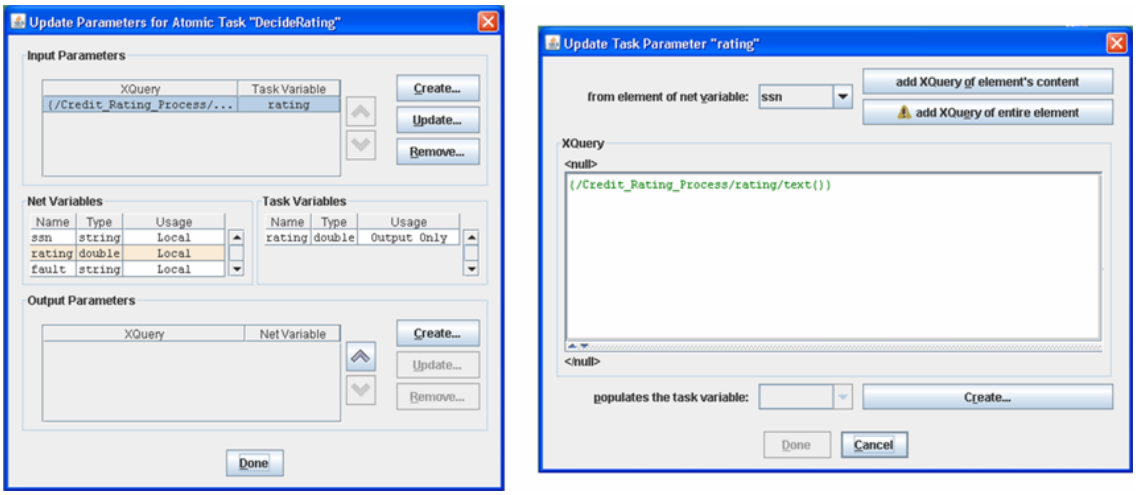


Figure 5.10: Parameter definition for task Decide Rating

Now we have completed the control flow and the data definition of the credit rating process. The specification will pass the syntax check in the YAWL editor and shows that "No design-time engine validation problems were founded in this specification". The last step before deployment is to specify the resource details for each of the manual tasks (i.e. ReceiveSSN, DecideRating, and ReportFault). In Chapter 4, Section 4.11 illustrates how to allocate resources to a manual task via the resource manager wizard. To keep things simple, we will choose to not specify any resourcing details for those task; in doing so, each of those tasks will be assigned the default settings: that offering, allocating, and starting a work item are all to be done by the User (at run time).

Finally, we save the "CreditRatingProcess" to file, which can be deployed (uploaded) in the engine and executed by launching a case.

Examples of Design-time/Run-time Errors

The above YAWL specification is both syntactically and semantically well formed, and can be executed without any problem in the Engine. Now we will introduce some errors into the above specification to see what we will encounter via design-time or run-time validation. These errors are considered to be common when designing (especially large) YAWL specifications.

Error 1: Missing Data Assignment for Input Variable

Assume that we forget to specify the mapping from net variable *fault* to task variable *fault* in the input parameter definition for task ReportFault (see Figure 5.11). This results in two syntax errors after validation of the "CreatRatingProcess" specification in the Editor, as shown in Figure 5.11.

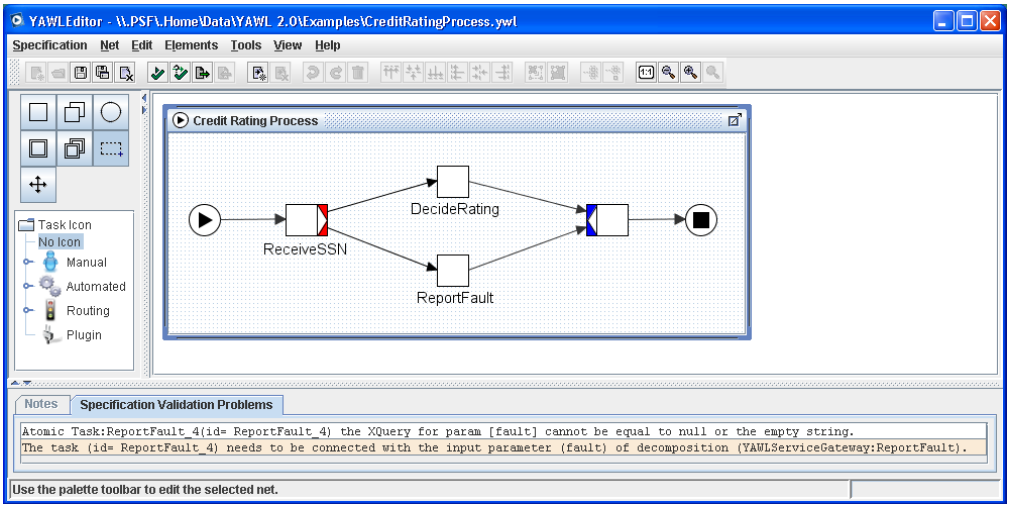

YAWLEditor - \\.PSF\.Home\Data\YAWL 2.0\Examples\CreditRatingProcess.ywl
Specification Net Edit Elements Tools View Help
Credit Rating Process
DecideRating
ReceiveSSN
ReportFault
Task Icon
No Icon
Manual
Automated
Routing
Plugin
Notes
Specification Validation Problems
Atomic Task:ReportFault_4(id= ReportFault_4) the XQuery for param [fault] cannot be equal to null or the empty string.
The task (id= ReportFault_4) needs to be connected with the input parameter (fault) of decomposition (YAWLServiceGateway:ReportFault).
Use the palette toolbar to edit the selected net.

Figure 5.11: An invalid specification with missing data supply for an input variable

Error 2: XQuery with Invalid Semantics

Assume that we use XQuery "/ReceiveSSN/ssn" but not "/ReceiveSSN/ssn/text()" in the output parameter definition for task ReceiveSSN (see Figure 5.12). This modified mapping is incorrect because it passes "<ssn> some social security number </ssn>" from task variable *ssn* to net variable *ssn*. However, the mapping has a valid syntax (because both variables are strings) and thus passes syntax validation in the YAWL Editor. But at run time, after the user submits his/her social security number (via task ReceiveSSN), an "bad process definition" error page as shown in Figure 5.12 will appear, indicating a failure has occurred validating the XQuery. Also, the executed credit rating process is halted.

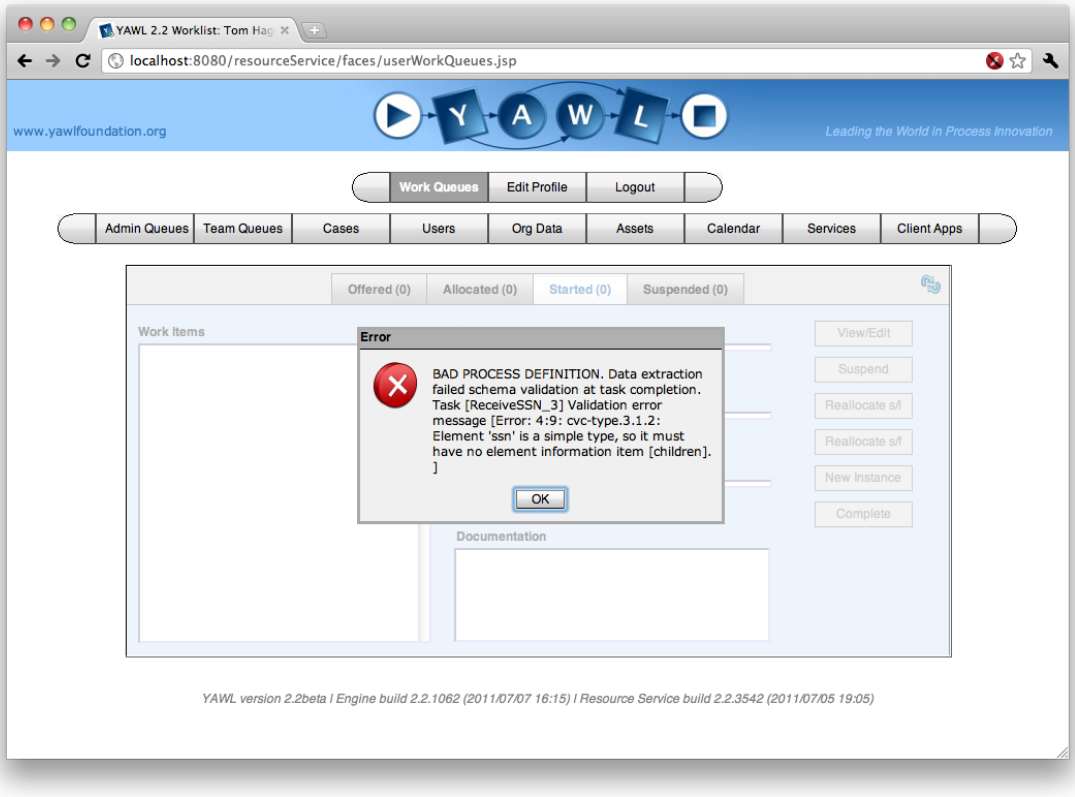


Figure 5.12: An error indicating invalid semantics of an XQuery used in the specification

5.5.2 Example 2: Simple Make Trip Process

This process provides a trip booking service. When running this process, the user is first asked to register for the trip. The registration information includes: customer name, trip start date, trip end date, whether to include booking a flight, hotel, and/or car, and customer's payment account number. After the registration, the booking tasks may be executed in parallel according to the user's requirements, and the booking details are also provided in each executed task. After all the booking tasks complete, the user is then asked to make payment for the trip, and the process ends.

YAWL Specification

Figure 5.13 shows the YAWL net specifying the above simple make trip process. There are five labelled tasks: "register" for registering for the trip; "pay" for making payment; and the other three tasks for making the corresponding bookings. The task "register" has an OR split decorator, and the task "pay" has an OR join decorator.

Figure 5.14 shows the data type definitions in this process. There are two new data types: *tripRegistrationType* comprising information of trip start date (*startDate*), trip end date (*endDate*), whether to book a flight (*want_flight*), hotel (*want_hotel*) and/or car (*want_car*), the customer's payment account number (*payAccNumber*); and *dateType* comprising information of *year*, *month* and *day*, e.g., both *startDate* and *endDate* are of *dateType*.

Figure 5.15 shows the net level variable definitions for the process. All are local variables of string type except that "registrInfo" is an output only variable of *tripRegistrationType*. Also, the variable "customer" has an initial value of "Type name of customer" (as a prompt for the customer to enter his/her name).

Figure 5.16 shows the parameter definition of task "register" with two task variables. The input & output

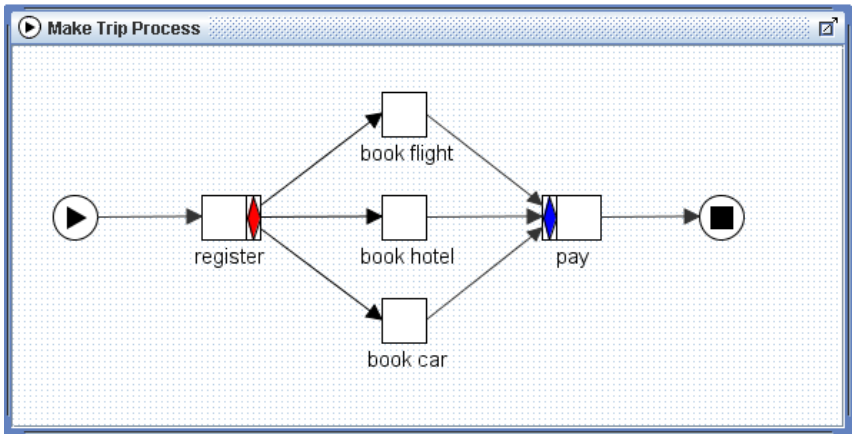


Figure 5.13: The simple "Make Trip Process" net

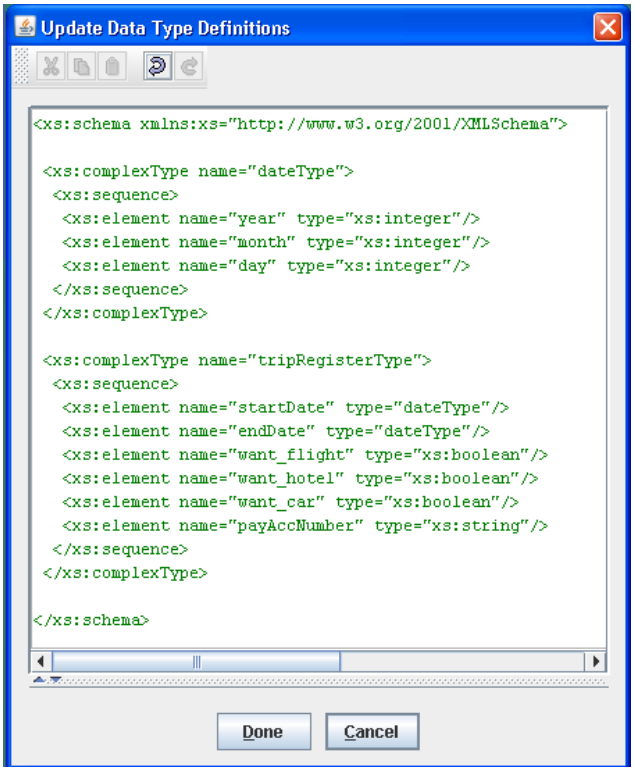


Figure 5.14: Updated data type definitions

variable *customer* gets the customer's name, and then passes it to the net. The output only variable *registrInfo* requests registration information from the customer, and then passes the data to the corresponding net variable via the XQuery "{/register/registrInfo/*}".

Figure 5.17 shows the flow definition at task "register". The predicate for the flow leading to task "book flight" is "/Make_Trip_Process/registrInfo/want_flight='true'". Similarly, the predicate associated with the flow leading to task "book hotel" or "book car" is to determine whether the variable *want_hotel* or *want_car* has a boolean value of "true" or "false". Note that this flow definition is defined with an OR split, so that any number of the flows to booking tasks can be taken.

Figure 5.18 shows the parameter definition of task "book flight" with four task variables. The three input only variables get data from the net via appropriate XQueries. Note that both *startDate* and *endDate* get

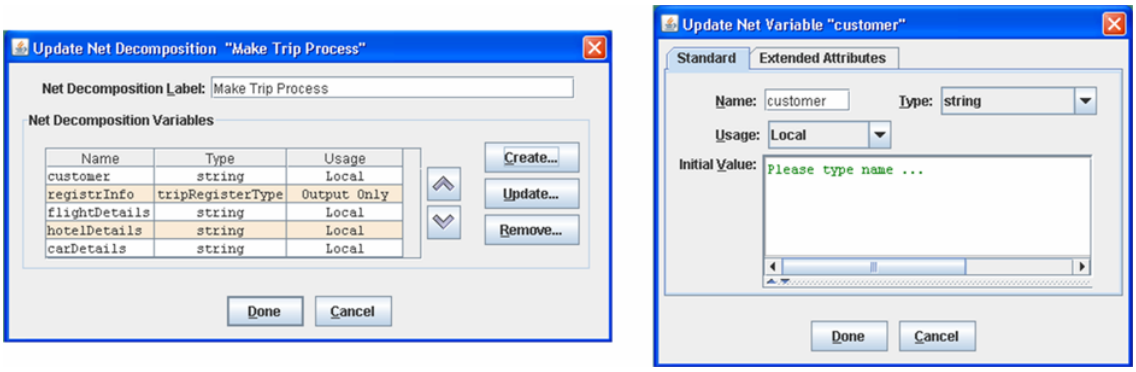


Figure 5.15: Net variable definitions

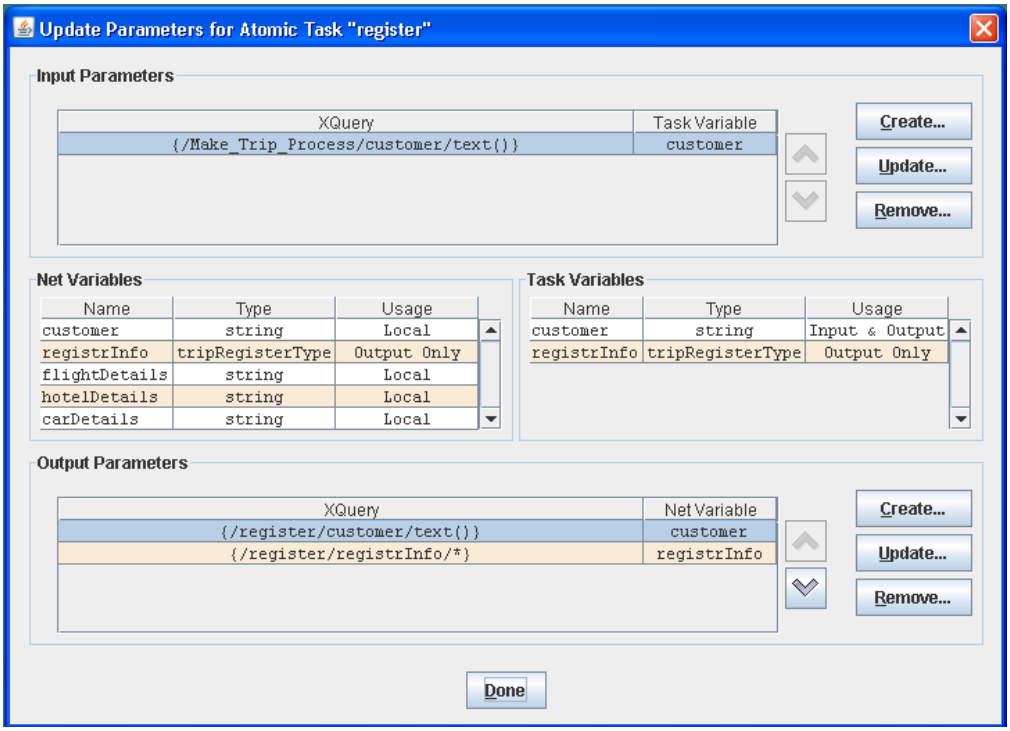


Figure 5.16: Parameter definition for task "register"

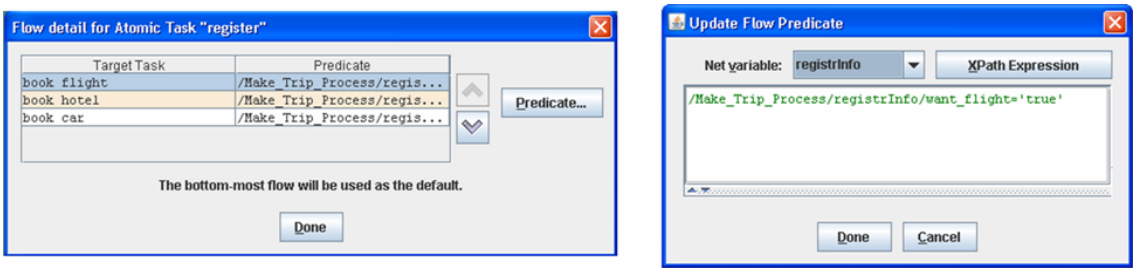


Figure 5.17: Flow definition at task "register"

data from the net variable *registrInfo*. There is one output only variable called *flightDetails*, which requires the information from the customer, such as his/her preferable airlines or even an exact flight number. The

parameter definitions of tasks "book hotel" and "book car" are specified in a similar way, except that the output only variable is *hotelDetails* or *carDetails*.

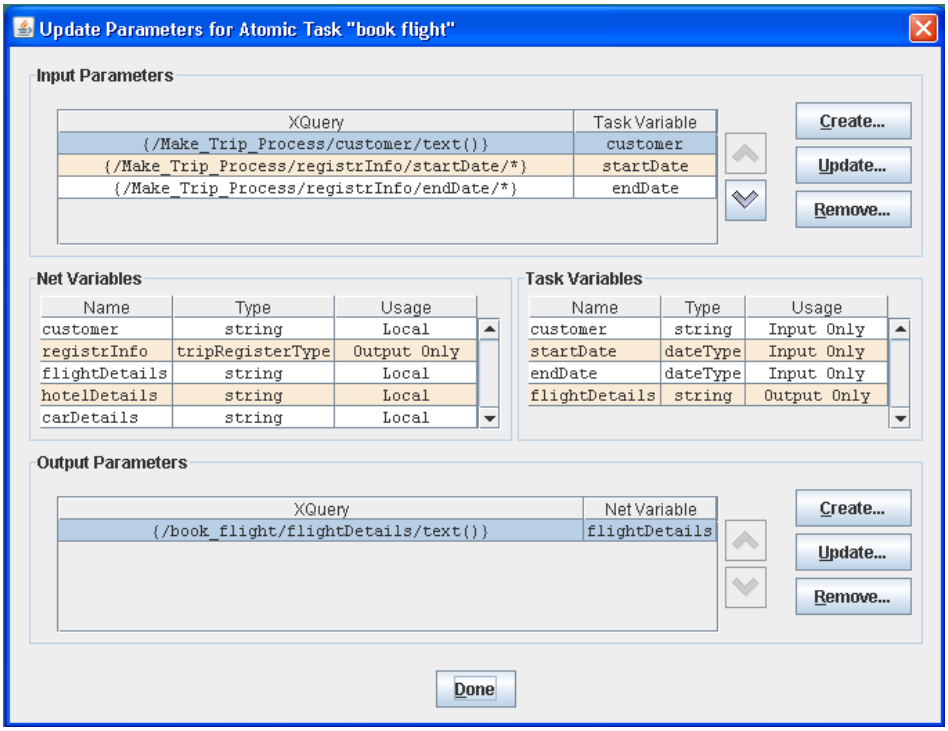


Figure 5.18: Parameter definition for task "book flight"

Figure 5.19 shows the parameter definition of task "pay" with five task variables. These are all input only variables and they get data correspondingly from those net variables with the same names.

5.5.3 Example 3: Make Trip Process with Multiple Instance Composite Tasks

This process provides a booking service for a trip that has several legs. For each leg, the same simple make trip process in the previous example will be executed. As a result, we obtain a more complex Make Trip process by involving a multiple instance composite task for execution of the simple make trip process for each leg. Also, the customer is provided with a subtotal of the payment for each leg, and the subtotals for all the legs in the trip will be calculated into a total payment at the end of the process.

YAWL Specification

Figure 5.20 shows the YAWL net specifying the above make trip process. There are two nets: the root net called "make trip" and the subnet specifying details for the composite task "do itinerary segment", which is basically the simple "make trip" net in the previous example.

Figure 5.21 lists the data type definitions in the "make trip" net. There are five new (user-defined) data types. The *itineraryType* contains a list of itinerary segments of *itinerarySegType*, which each comprises information of *departure location*, *destination*, *startDate*, *endDate*, *flightDetails*, *hotelDetail*, *carDetails*, and *subtotal*. The *legsType* is a set of legs of *legType*, which provides the information of *departure location* and *destination*. Finally, the *serviceType* specifies whether to book a flight, hotel and/or car (as alternative to the previous example, we group these needs together this time).

Figure 5.22 shows the net variable definitions for the "make trip" net. There are three new variables, *itinerary*, *legs*, and *subTotals*, as compared to the previous simple "Make Trip Process" net in Section 5.5.2.

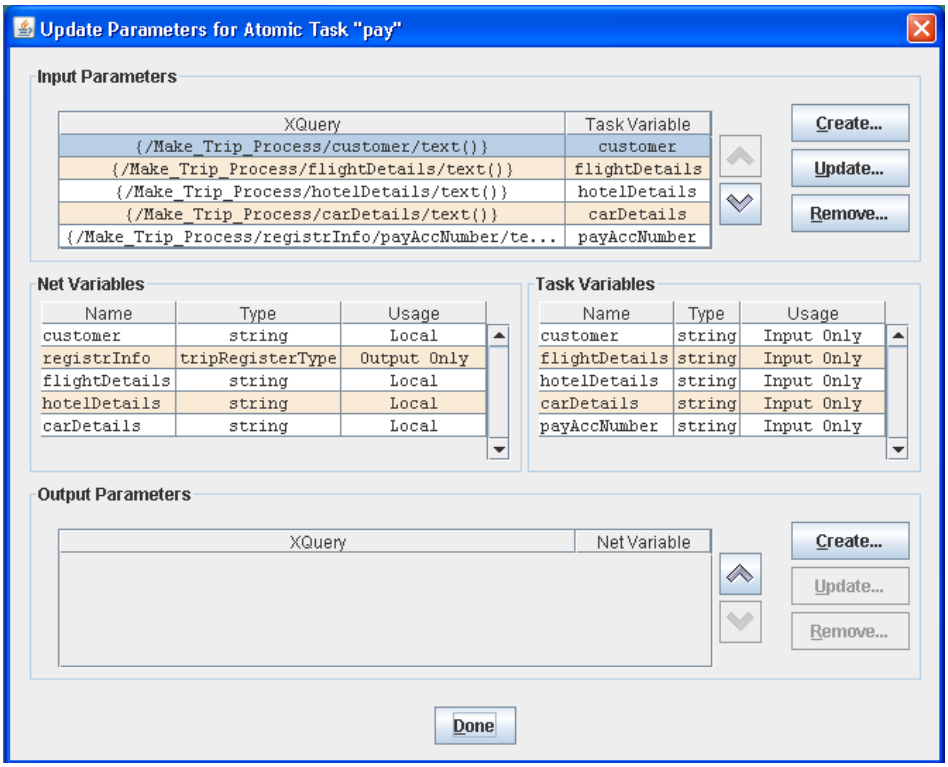


Figure 5.19: Parameter definition for task "pay"

Figure 5.23 shows the parameter definition of task "register". There are three task variables, *customer*, *legs*, and *payAccNumber*, with appropriate input or output parameter definition.

Figure 5.24 shows the parameter definition of task "pay". There are four variables which are all input only variables. Note the input parameter definition of the mapping from variable *subTotal* to variable *total*. The XQuery function *sum*() calculates a *total* sum of *subTotals* from each itinerary segment.

Figure 5.25 shows the parameter definition of the multiple instance composite task "do itinerary segment". There are nine task variables, which are also the net variables of the subnet of this task. All except *startDate*, *endDate*, and *serviceRequired* are input & output variables conveying data between root net and the subnet. The variable *serviceRequired* contains information only used within the subnet, and is therefore defined as a local variable. The *startDate* and *endDate* variables are output variables reporting the user input back to the corresponding net variables. Also, the input parameter definition for variable *leg* and the output parameter definition for variable *itinerary* are both determined by the task instance queries (see below).

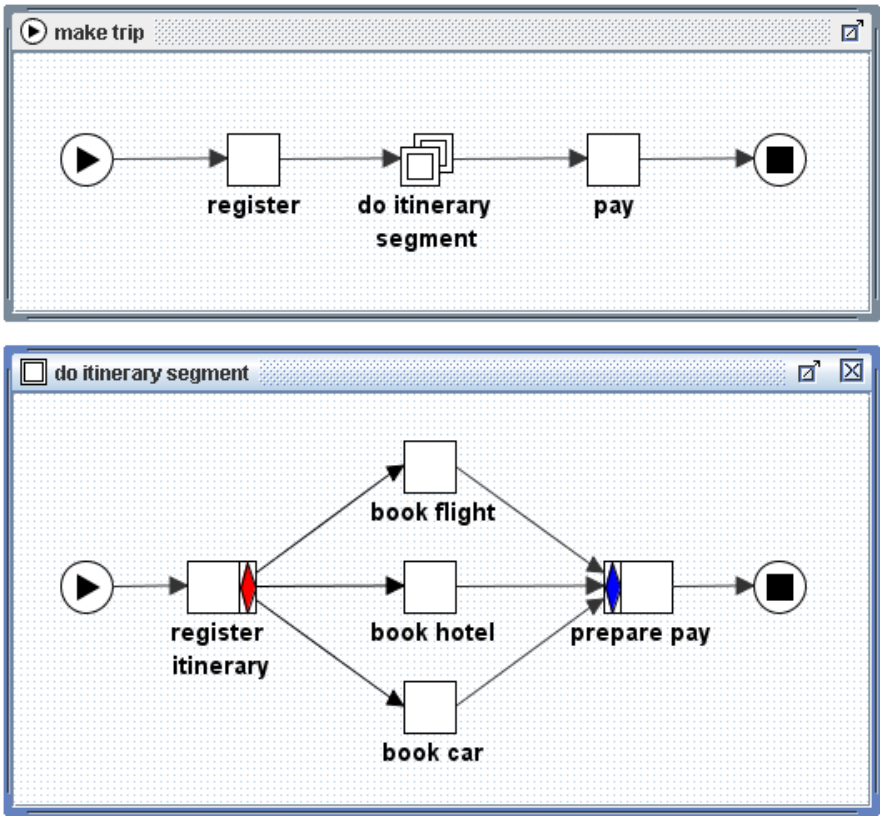


Figure 5.20: The "make trip" net with a multiple instance composite task "do itinerary segment" and the corresponding subnet

Figure 5.26 shows the instance details for task "do itinerary segment". The left tab window titled **Bounds** is for specifying the task attribute data, i.e. the maximum and minimum number of instances allowed and the threshold value. The right tab window titled **Queries** is for defining the multiple instance data specific to individual execution instances of task "do itinerary segment" for each *leg* within one itinerary (i.e. a single process instance). There are four queries. Firstly, an *accessor query* manipulates the overall data carried by root net variable *legs* before the data is split out to each individual *leg*. This query determines the input parameter definition for variable *leg*. Secondly, a *splitter query* separates the unique values from the overall data carried by variable *legs*, and passes a unique value to variable *leg* associated with each instance. The data returned on completion of an instance is an XML document. Thirdly, an *instance query* transforms such an XML document to a form that is suitable for aggregation of data to the higher level, i.e. the root net "make trip". This query determines the output parameter definition for root net variable *itinerary*. Finally, an *aggregate Query* generates an overall result and passes the data to variable *itinerary* on completion of all instances of task "do itinerary segment" within a single itinerary.

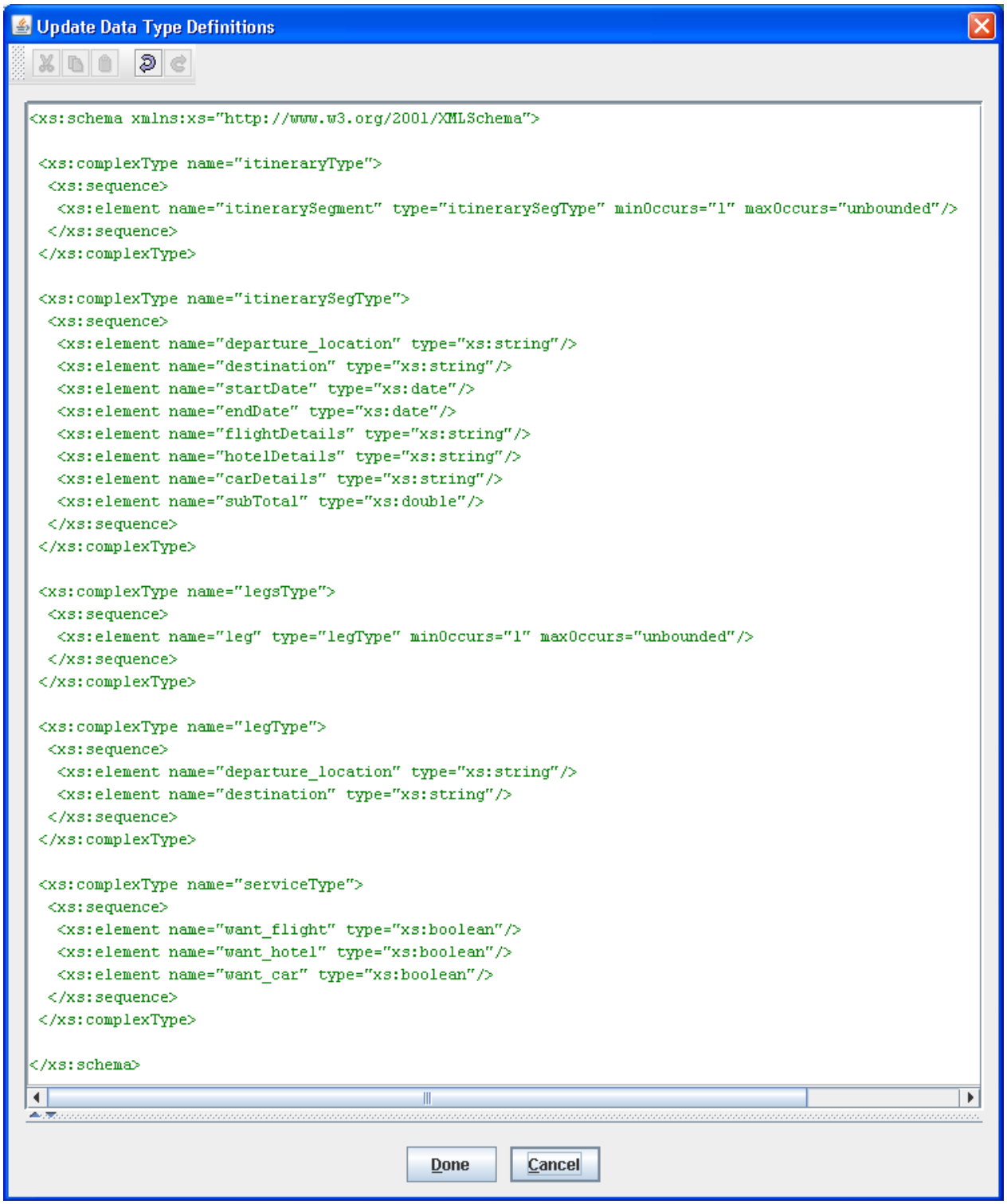


Figure 5.21: Updated data type definition for the "make trip" net

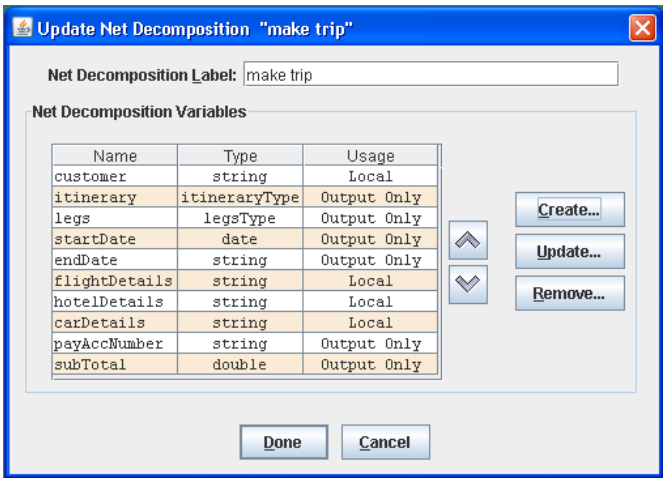


Figure 5.22: Net variable definitions for the "make trip" net

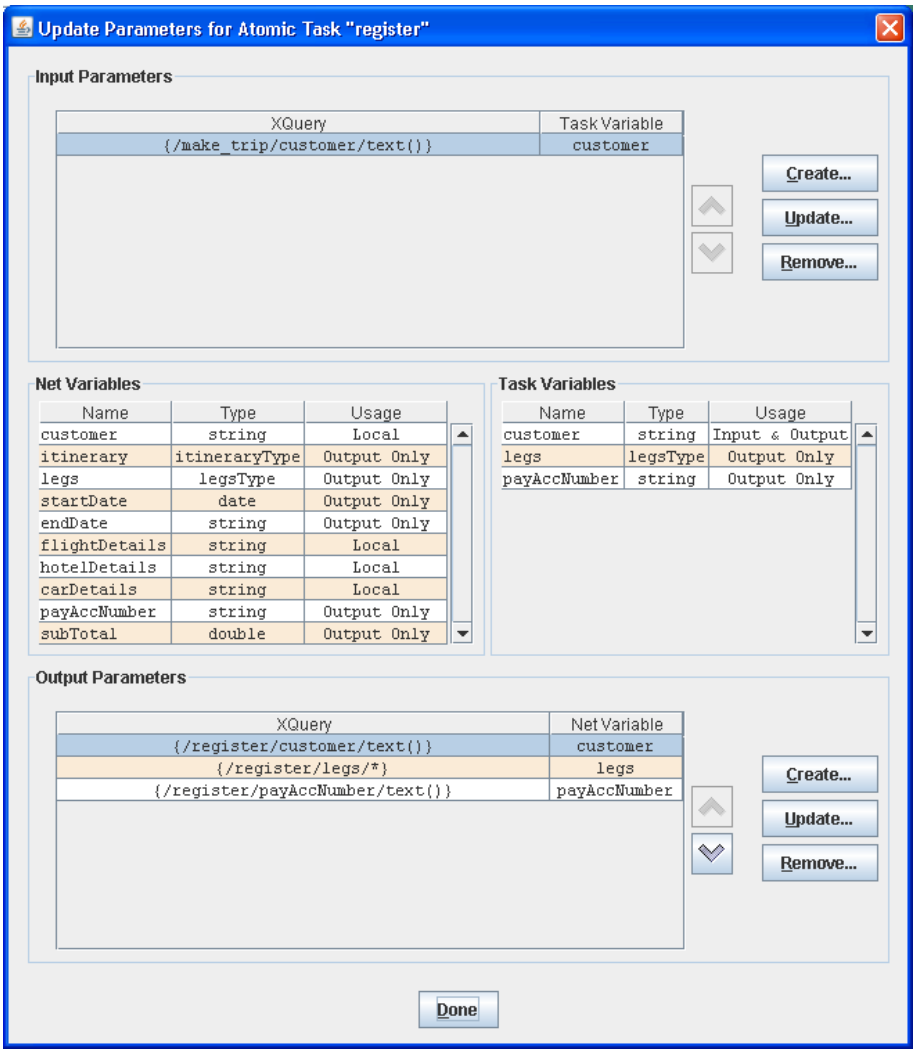


Figure 5.23: Parameter definition for task "register"

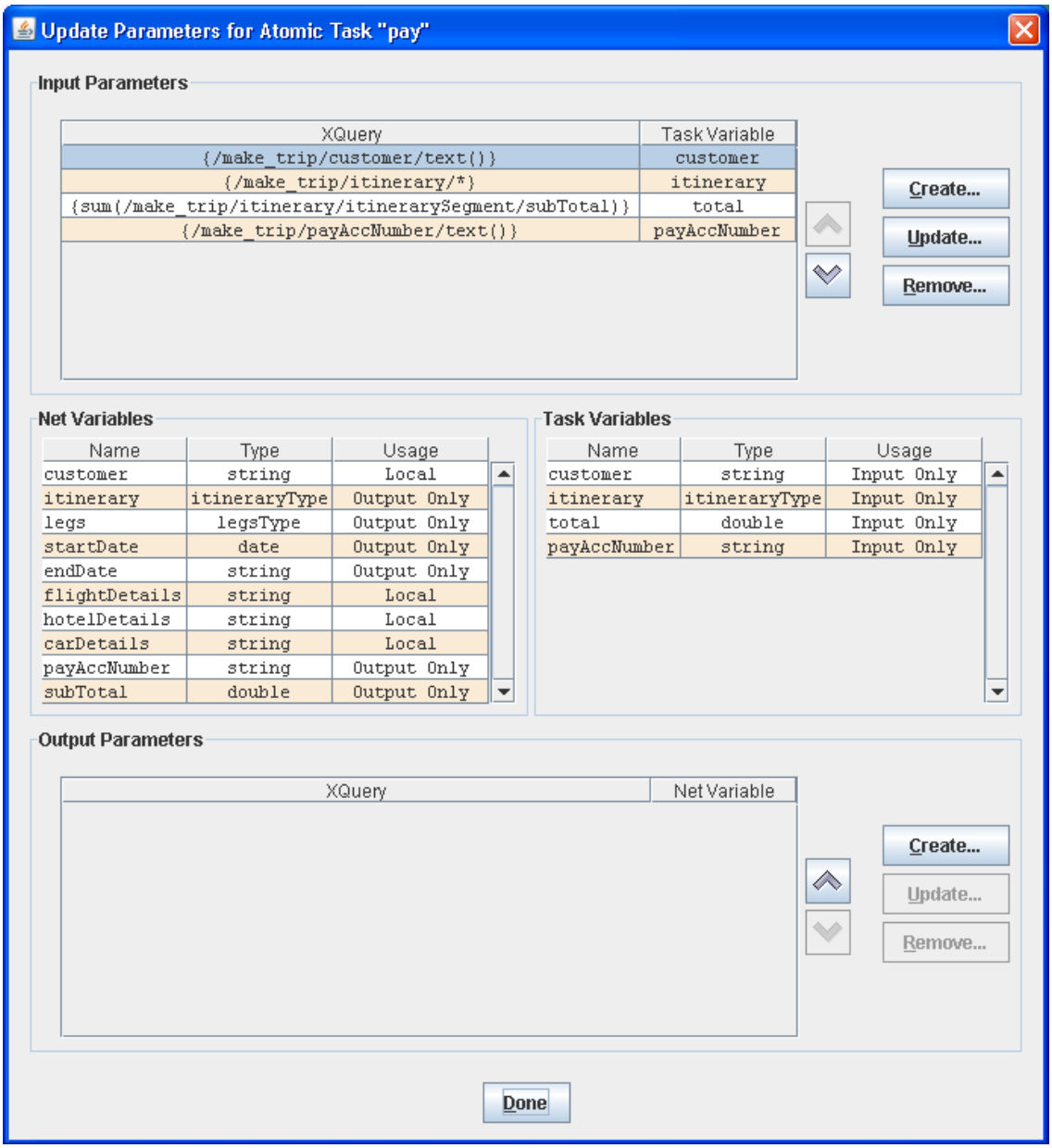


Figure 5.24: Parameter definition for task "pay"

The subnet of task "do itinerary segment" specifies the simple "make trip" process that is similar to the one in Section 5.5.2. Thus, we do not go into every detail, but provide the parameter definitions for tasks "register itinerary", "book flight" and "prepare pay" in Figure 5.27 to Figure 5.29, respectively. The parameters for the other two tasks "book hotel" and "book car" are defined in a similar way to those of task "book flight".

Note Since the variable *subTotal* is of *double* type, the XQuery function *number*() is used to extract data from the variable.

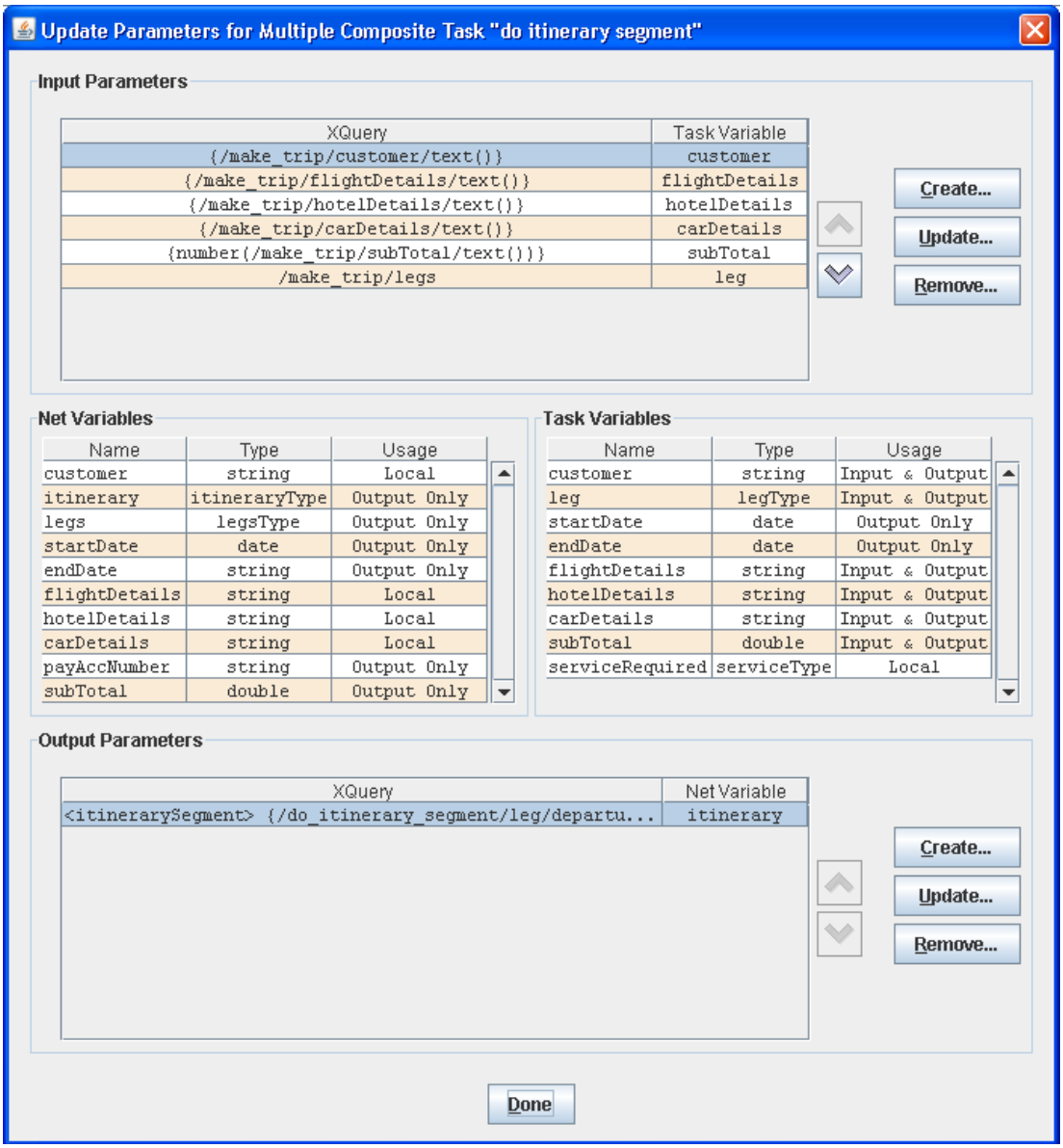
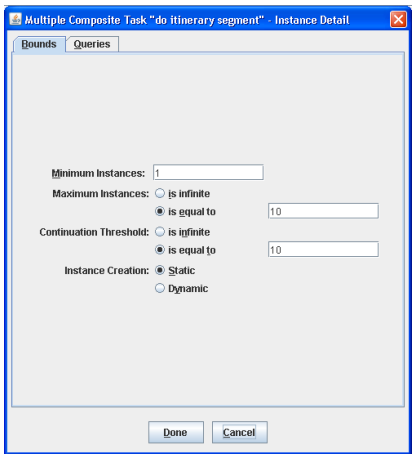


Figure 5.25: Parameter definition of task "do itinerary segment"



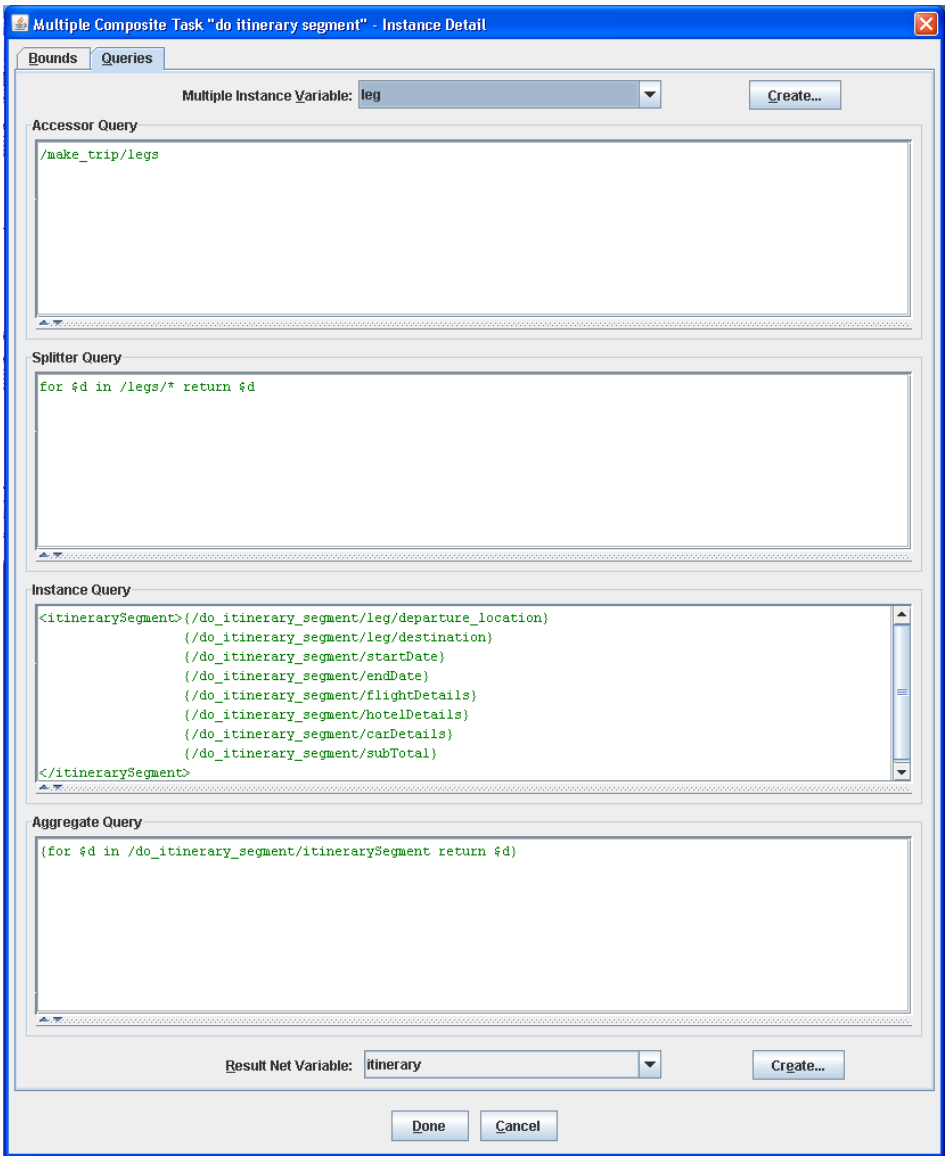


Figure 5.26: Instance details for task "do itinerary segment"

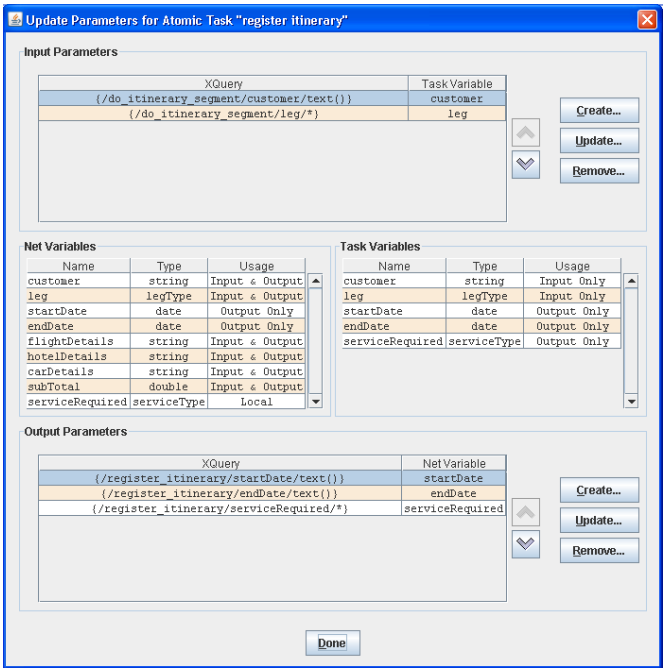


Figure 5.27: Parameter definition for task "register itinerary"

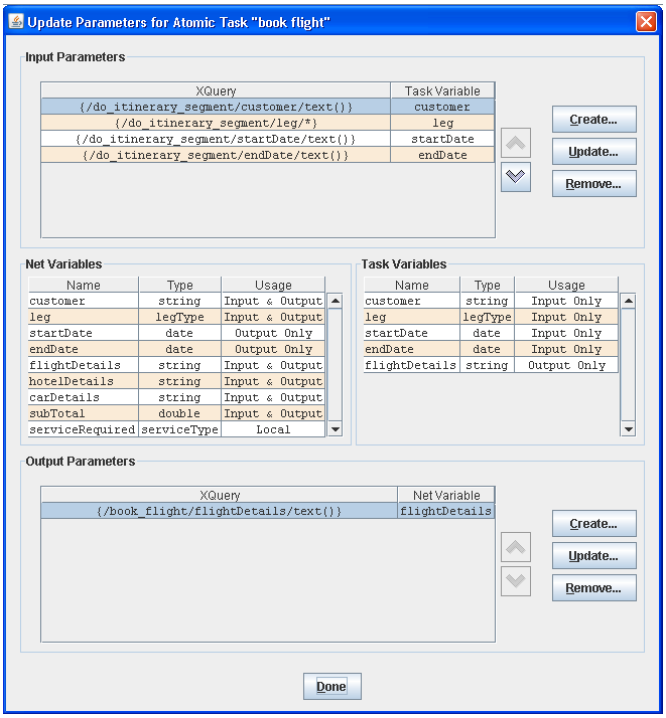


Figure 5.28: Parameter definition for task "book flight"

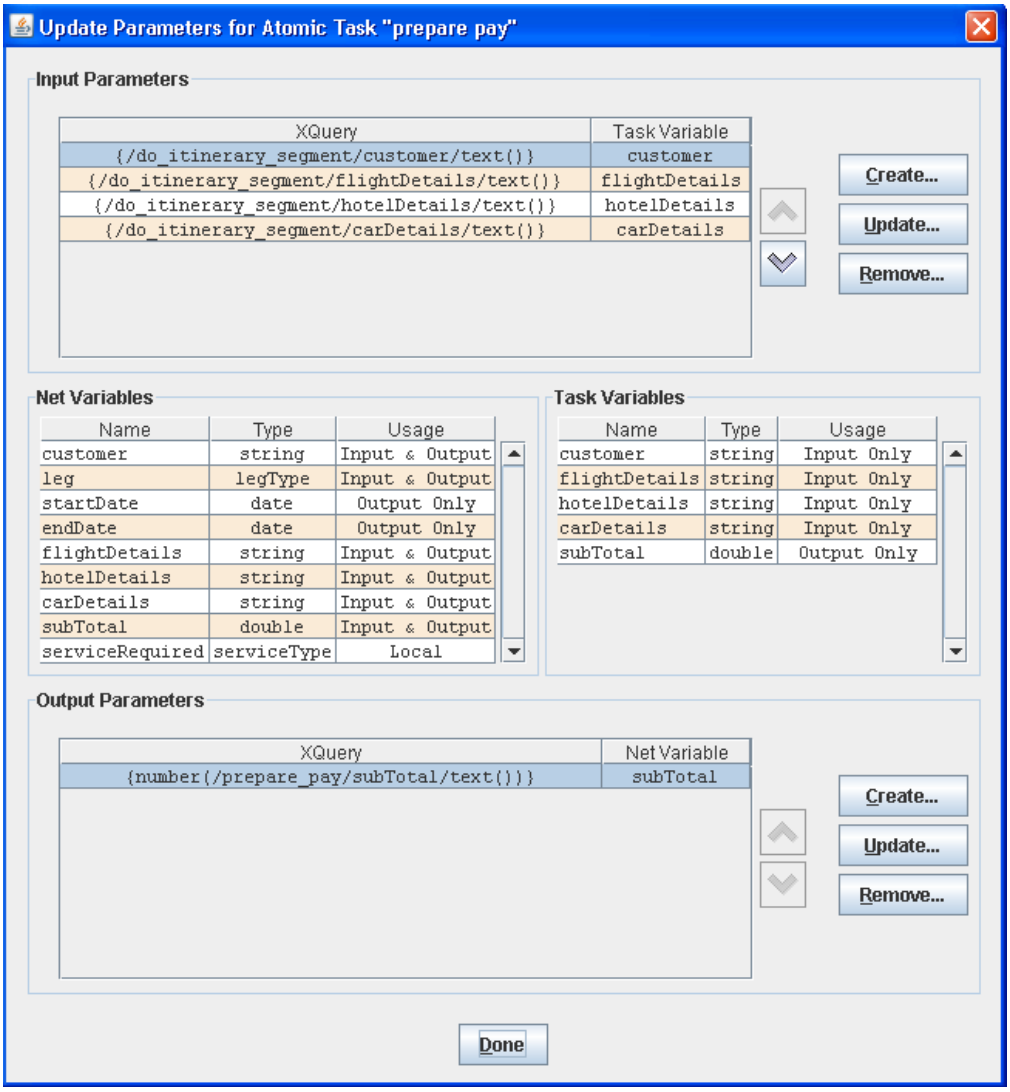


Figure 5.29: Parameter definition for task "prepare pay"

Chapter 6

The Runtime Environment

This chapter provides an overview of the runtime environment from a user perspective.

When a YAWL workflow specification has been completed in the Editor it can be saved to a file, the contents of which are in an XML format that can be interpreted by the YAWL Engine. The specification file contains descriptions of each of the three perspectives of a process: control-flow (task sequences, splits, joins etc.); data (variables, parameters, predicates etc.); and resourcing (participants, roles, allocators, filters etc.). However, the Engine is responsible only for the control-flow and data perspectives – it essentially ignores the descriptors for resourcing contained in a specification file, instead passing responsibility for the resource perspective to a dedicated custom service. In the core YAWL environment, a custom service, called the *Resource Service*, is supplied to provide comprehensive support for the resource perspective.

The resource perspective of Business Process Management (BPM) is concerned with the way work is distributed to resources. It is here that the link between the process model and the organisational model is formalised. This is a very important perspective in BPM and one that has not had as much attention as the control-flow perspective. In fact the state-of-the-art in BPM environments typically lacks sufficient support for the resource perspective (consult the Workflow Patterns Home Page at www.workflowpatterns.com for more details).

The realisation of the resource perspective in YAWL 2.0 is based on the analysis work reported in a technical report on newYAWL [21] and Nick Russell's PhD thesis [22][1].

The Resource Service is a large custom service that contains a number of components, primarily a *Resource Manager* that is responsible for the allocation of tasks to human users (referred to as 'participants'); a *Worklist* that comprise a series of web forms that provide a user interface to processes and process management; *Administration Tools* that comprise a series of web forms to administer the Engine, processes and organisational data; a *Dynamic Forms Generator*, which creates web forms on-the-fly for the presentation of work item data to participants so they can be performed and completed; and a *Codelet Coordinator* that manages the execution of codelets for automated tasks.

ASIDE: The Resource Service provides functionality to support the identified resource patterns [19] and associated activities. However, as a custom service, it is completely removed from the operation of the Engine. This means that developers are free to develop other custom services that communicate directly with the Engine (and thus bypassing the Resource Service), although support for the resource perspective would also be lost. Alternately, the Resource Service provides a number of interfaces that expose the full functionality of the service, which developers may exploit to 'override' service components. For example, other types of worklist services may be developed that leverage the resource management capabilities of the Resource Service but present work to users in different or novel ways; external organisational data sources may be used in place of the default internal data model supported by the Resource Service; Custom Forms may be defined to display work item data, rather than using the default, dynamically generated forms; and so on. Also, the Resource Service is *extendible* in many ways, for example developers may add new

[1] For a discussion of how the workflow resource patterns have been realised in newYAWL, see appendix A.3 starting on page 373 of [22].

allocation strategies, filters, constraints, codelets etc. at any time, which immediately become available for use in the service and the Editor. For more information, please consult the *YAWL Technical Manual*.

Since the Resource Service provides the default set of tools for user interaction with the YAWL system, this chapter describes the runtime environment by describing the use of the service. Configuration and Administration functionality is described first, followed by the various user interactions.

6.1 Engine Configuration Settings

The Engine has several configuration parameters that may be set in its *web.xml* file, which is located in the folder *\webapps\yawl\WEB-INF*. Below is the list of available parameters that are specific to the Engine, what they are used for and what values may be assigned to them.

- **EnablePersistence**: When set to true (default), allows the engine to persist (backup) current process data to a database, so that in the event of the Engine being restarted, the 'work-in-progress' can be restored. There is rarely any need to disable persistence, and in any case this setting should always match the 'EnablePersistence' settings of the Resource Service and the Worklet Service.

- **DefaultWorklist**: Each and every task that is enabled by the Engine during process execution is passed to a YAWL custom service for processing. Each task that is not explicitly mapped to a custom service at design time is dispatched to the *Default Worklist Handler*. That is, the default worklist handler is the fall-through service that handles all tasks that aren't explicitly associated with a chosen service. Therefore, the Engine requires a service to be nominated for this purpose. By default, the Resource Service, with its built-in worklist handler, serves this role, but any other service may be nominated as the default worklist by configuring this parameter. The value of the parameter is the URL of the worklist, and its password, separated by a hash character (#). The password must match the one the service will use to log onto the Engine.

- **EnableLogging**: The Engine records extensive data about running processes to its process log for later analysis and to keep an historical archive. Process logging is enabled by default when persistence is enabled. If persistence is enabled, setting this parameter to 'false' will disable process logging. If persistence is disabled, the value of this parameter has no effect.

- **AllowGenericAdminID**: This parameter allows for the generic 'admin' user account to be disabled. If the parameter's value is 'true', services and applications may connect to the YAWL engine using the generic administrator account 'admin', password 'YAWL' (or some other password if the password has been changed – see Section 6.4.4). If the parameter's value is 'false', each connecting service and application must connect using a unique account previously registered with the engine.

- **EnableHibernateStatisticsGathering**: When set to 'true', the hibernate database layer will collect statistics of all operations for later perusal. When set to 'false', the default, hibernate statistics collection is disabled. There is a slight performance overhead associated with statistics gathering.

- **InitialisationAnnouncementTimeout**: When the Engine completes its initialisation and is running, it sends an event announcement to all registered custom services to notify them that it is ready to execute processes and receive requests. This parameter allows you to set the maximum number of seconds the engine will spend trying to deliver the event to each registered service before giving up. The specified value should cover the period between the moment the Engine has fully initialised and the moment the server hosting a custom service is ready to accept HTTP connections. The value can be any positive integer, and defaults to 5 seconds if the value is missing or invalid.

- **InterfaceXListener**: The fully qualified URI of a custom service that wishes to receive event notifications on Interface X (the exception handling interface). Multiple URIs can be specified, separated by semi-colons ';'. Note that services can also register themselves as Interface X Listeners programmatically. See the *Technical Manual* for more details.

- **ObserverGateway**: The fully qualified class name of an ObserverGateway implementation. Multiple implementations may be specified, separated with semi-colons ';'. See the *Technical Manual* for more information about Observer Gateways.

6.2 Resource Service Configuration

The Resource Service has a number of configuration parameters that may be set in the service's *web.xml* file, which is located in the folder *\webapps\resourceService\WEB-INF*. Below is the list of available parameters that are specific to the Resource Service, what they are used for and what values may be assigned to them.

- **EnablePersistence**: When set to true (default), allows the service to persist (backup) current work queue data to a database, so that in the event of the Engine being restarted, the 'work-in-progress' can be restored. There is rarely any need to disable persistence, and in any case this setting should match the 'EnablePersistence' settings of the Engine and the Worklet Service.

- **OrgDataSource**: While the Resource Service offers an internal organisational database by default, it also supports organisational data being used that is stored in existing, external data sources. This is especially beneficial for sites that want to use org data already stored in HR Systems and so on. External data sources may be 'mapped' to YAWL by implementing a java class to take care of the necessary mappings (see the technical manual for details). This parameter allows for the specification of that mapping class name. The default setting is 'HibernateImpl', the internal Resource Service mapping class.

- **ExternalUserAuthentication**: When an external organisational data source is configured for use by the Resource Service, a choice can be made regarding the logon authentication of users, which specifies whether the Resource Service will take responsibility or if authentication will be handled by the mapping class (configured above). When this parameter is set to false (the default), user passwords are encrypted and stored within each user record, and authentication is handled within the Resource Service. When it is set to true, user authentication is deferred to the currently implemented external organisational data source, and passwords are sent to the data source as plain text (rather than the default encryption). It is up to the external data source to provide valid user authentication in this case. A setting of true is only relevant if an external data source is active; if the default YAWL org database is in use, this setting is ignored.

- **AllowExternalOrgDataMods**: By default, when an external organisational data source is configured for use by the Resource Service, that data is not allowed to be modified via the Resource Service's administration web forms (i.e. data from an external data source is considered read-only by default). When this parameter is set to true, modification of data from an external data source via the administration web forms is allowed. A setting of true is only relevant if an external data source is active; if the default YAWL org database is in use, this setting is ignored.

- **OrgDataRefreshRate**: This parameter provides for the setting of a regular time interval to refresh the organisational data caches in the Resource Service. This is particularly important when the org data is sourced externally, and that external source is 'live' (regularly updated through other systems). If an external data source is not being used, then the parameter's value should be left at -1 (the default, interpreted as 'never refresh'), since the internal data sources are only ever updated through the Resource Service. The parameter value specifies the number of minutes to wait between refreshes.

- **BlockOnUnavailableSecondaryResources**: A work item may have zero or more secondary resources (i.e. non-human resources, and human resources that aren't primarily responsible for the work item's performance) allocated to it. For each work item that has secondary resources allocated to it, setting this parameter to 'true' will prevent the work item from being started if any of its secondary resources are unavailable. When set to 'false' (the default), the missing resource(s) will be noted in the log only, but the work item will be allowed to start.

- **EnableLogging**: The Resource Service also records extensive data about running processes to its process log for later analysis and to keep an historical archive. Process logging is enabled by default when persistence is enabled. If persistence is enabled, setting this parameter to 'false' will disable process logging. If persistence is disabled, the value of this parameter has no effect.

- **LogOffers**: By default, all resourcing events (offer, allocation, start, reallocate, etc.) are written to a process log. If there are large numbers of participants in the organisational model, or work items are typically offered to a large number of potential participants, the logging of all offers may incur some processing overheads for little return (e.g. there may be instances where a work item is offered to several hundred participants – the members of that set can always be derived from design time resourcing parameter settings in any case). By setting this parameter to 'false', no offer events will be logged; logging of all other events will still occur.

- **DropTaskPilingOnLogoff**: A participant who has been granted the authority to 'pile' a certain task, may then explicitly and manually choose to do so, which means they will receive all instances of that task, across all current and future instances of the process that contains the task. When this parameter is set to true, piling of tasks for a participant will cease when the affected participant logs out. When this parameter is set to false (the default), piling of tasks for a participant will continue, whether the participant is logged on or not, until it is explicitly ceased by the affected user or an administrator. This setting is ignored (i.e. treated as 'true') if persistence is not enabled. This parameter applies globally to *all* piled task participants.

- **GenerateRandomOrgData**: This parameter allows you to quickly fill the organisational data base with randomly generated data (participants, roles, positions, capabilities and org groups), which is especially useful for testing purposes, or to examine the capabilities of YAWL without first having to manually populate the org database with real (or dummy) data. A parameter value of between 1 and 100 will generate that number of randomised participants (with associated membership of roles etc.); a value greater than 100 is treated as 100. A value of -1 (the default) turns off random org data generation. If you do make use of this feature, don't forget to reset the value to -1 after the generation is done.

- **ExternalPluginsDir**: The Resource Service supports the ability to extend its functionality through a number of 'pluggable' interfaces. These interfaces allow developers to provide their own pluggable classes (i.e. codelets, allocators, filters, constraints and so on). By default, these classes are inserted into the internal YAWL class packages, which becomes problematic whenever YAWL has a version upgrade. The 'ExternalPluginsDir' parameter sets an external base directory for third-party plug-in classes. The base directory must refer to a location on the local disk, for example: "C:\yawlplugins". Several base directories can be provided, separated by semi-colons, for example: "C:\yawlplugins;C:\some\other\place". The service will expect to find classes to be located in sub-directories of the specified external directories matching their own package structure, and ending in the 'type' of the plugin (i.e. 'codelets', 'allocators', 'constraints' or 'filters'). For example, if the 'ExternalPluginsDir' is set "C:\yawlplugins" and there is a codelet file called 'MyCodelet.class' and it has a package 'com.example.yawl.codelets' (since its a codelet, it must end in 'codelets') then its full file path is expected to be "C:\yawlplugins\com\example\yawl\codelets\MyCodelet.class". If there are no external plug-ins, then this parameter can be commented out or the param-value can be left blank.

- **EnableVisualizer**: When set to true, an extra button will appear on user work queues to show work items via the Visualizer applet (assumes the visualizer is available). The default setting is false.

- **VisualizerViewSize**: When the Visualizer applet is enabled, this parameter configures the size of the Visualizer applet's view window. The value must be two comma-separated positive integers (width,height). If no value is given, or the value is invalid, a default of 800,600 will be used. When the visualizer is disabled, this parameter is ignored.

- **InterfaceX_BackEnd**: This parameter is commented out by default. When the commenting is removed, the extensions to the work queues required for the Worklet Service are enabled. When enabled, the value of this parameter must equal the valid URI of the Worklet Service

- **InterfaceS_BackEnd**: This parameter is commented out by default. When the commenting is removed, scheduling event announcements to a scheduling service listening on Interface S are enabled. When enabled, the value of this parameter must equal the valid URI of a running Scheduling Service.

6.3 Logging On

To log on to YAWL:

1. Start the YAWL engine by choosing the option "Start Engine" from the YAWL program menu (or by starting Tomcat directly);
2. Navigate to the Resource Service's web UI either by choosing "YAWL Control Centre" or by pointing your browser at `http://localhost:8080/resourceService`.
3. Login with an existing userid and password. First time logons (i.e. where there are no participants defined in the organisational database) should use the generic userid "admin" and password "YAWL".

Note that a participant with administration privileges will have available the full menu of actions (Figure 6.3 shows an example); ordinary participants and participants with some extra privileges will see a subset of those actions when they log on. The "admin" userid is a 'special' logon, which can be used for administrative tasks only – but because it is not a formal participant (i.e. it is not a logon associated with a unique person), it has no access to an individual work queue, so the menu options for 'Work Queues', 'Team Queues' and 'Edit Profile' are not available for the "admin" logon.

6.4 Administration

A workflow administrator can load new workflow specifications, can start cases for them, can manage all active work items, can register or remove custom services and client applications, and add, manage and remove participants, roles, positions, non-human resources and organisational groupings. In this section we will explore how these functions are achieved.

6.4.1 Case Management

To upload a new workflow specification, first click *Case Mgt* in the top menu, which displays in the screen shown in Figure 6.1. Upload the specification by browsing to the particular file and clicking the *Upload File* button in the *Upload Specification* panel. Only valid specification files with a .yawl or .xml extension can be uploaded.

When a specification is uploaded, it is validated against the YAWL specification schema for validity. If there is a problem with the upload, an appropriate error message is displayed in a popup dialog.

Cases can be launched for a specification by selecting it from the list of loaded specifications, then clicking the *Launch Case* button in the *Loaded Specifications* panel. If the specification has input parameters a form will appear asking for values for these parameters to be provided before the case is launched.

Note that attempting to upload a specification that has already been uploaded (i.e. same specification id and version) is not possible and will result in an error message to this effect being displayed. It is possible to have different versions of the same specification loaded at any one time (e.g. if a specification has been updated, but there are still cases running against the older version), but new cases may only be launched for the latest version uploaded.

To unload a specification from the Engine, select it and click the *Unload Spec* button in the *Loaded Specifications* panel. Note that an attempt to unload a specification will fail if there are any cases still executing against it.

The *Get Info* button in the *Loaded Specifications* panel will display some meta data about the selected specification – an example can be seen in Figure 6.2.

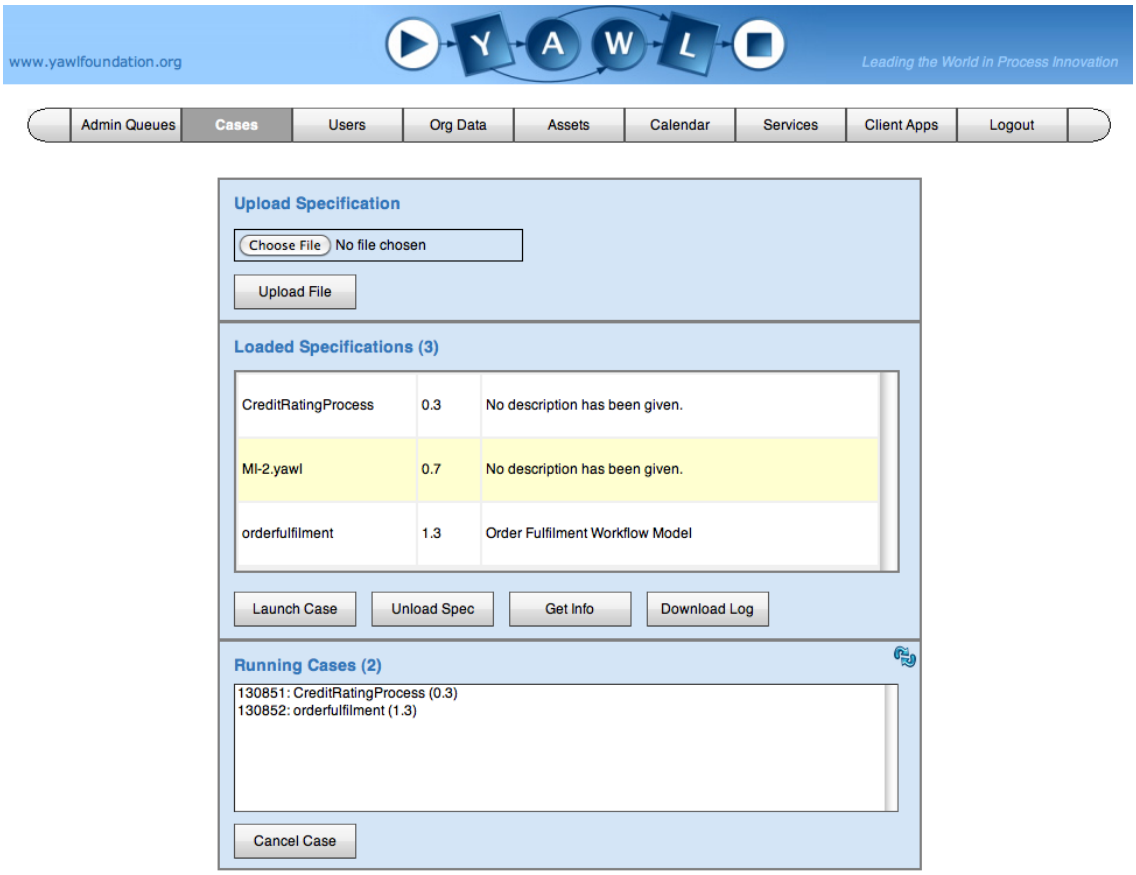


Figure 6.1: Case Management

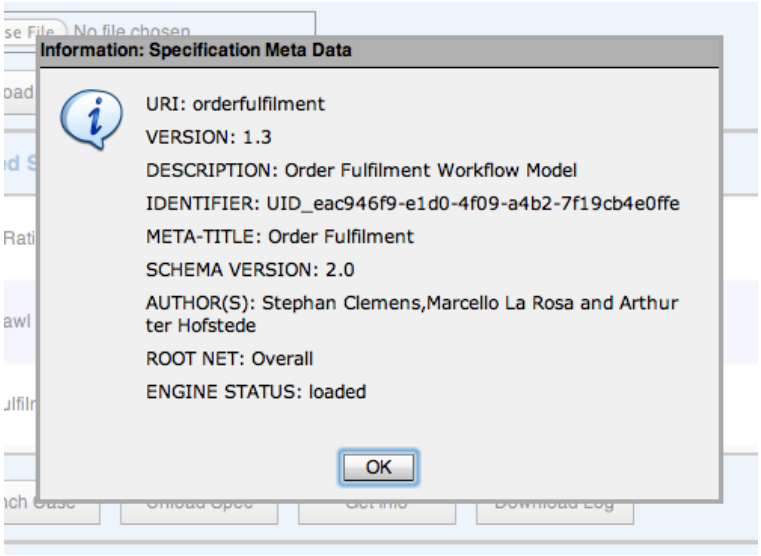


Figure 6.2: Specification meta data dialog

The fourth button in the *Loaded Specifications* panel is the *Download Log* button, which will generate and download a file containing the complete process log for the selected specification, in OpenXES format. The

log file produced can be read directly into the process mining tool ProM[2]. Note that the generation of a process log file may take some time, especially if there has been a large number of cases executed for the selected specification.

The *Running Cases* panel shows a list of all the cases currently executing in the Engine, in the form "case number: specification name (version)". While the list is refreshed whenever the page is loaded, you may also refresh the list contents by clicking on the *refresh* icon located at the top right of the *Running Cases* panel. A case can be cancelled at any time by selecting it from the list of running cases and clicking the *Cancel Case* button.

6.4.2 Admin Queues

An administrator can view all of the various work items that are currently active and their statuses in the Admin Queues Screen (see Figure 6.3). There are two Admin queues, each of which can be selected by clicking on the appropriate tab: *Worklisted*, which lists all the work items on participants' work queues, and *Unoffered*, which lists the active work items that do not currently reside on any participant's queues. From the *Unoffered* queue, an administrator can assign unoffered work items to the offered, allocated or started work lists of selected participant(s) via the buttons *Offer*, *Allocate* and *Start* respectively.

Figure 6.3: Administration Queues

From the *Worklisted* queue, an administrator can change the participant and/or the status of the work item through the *Reoffer*, *Reallocate* and *Restart* buttons. Reverting to a previous state is allowed using these buttons:

- If the current resource status is *Offered*, the work item may be *Reoffered* to one or more participants.
- If the current resource status is *Allocated*, the work item may be *Reoffered* to one or more participants, or *Reallocated* to a single participant.
- If the current resource status is *Started*, the work item may be *Reoffered* to one or more participants, *Reallocated* to a single participant, or *Restarted* to a single participant.

[2] http://processmining.org

While the queues are refreshed whenever the page is loaded, you may also refresh the queue contents by clicking on the *refresh* icon located at the top right of the work queues panel.

If the *Directly to me* checkbox is unchecked, when one of these buttons is clicked, a list of all participants will be displayed, from which selections can be made. If the checkbox is checked, the action triggered by the button click will occur as if the currently logged on participant had selected themselves from the list (thus bypassing the list display). The *Directly to me* checkbox is available only to participants with administrator privileges, but not to the generic "admin" userid (since "admin" is not a participant, it cannot have work items assigned to it).

The Resource Service maintains a local cache of active work items. On rare occasions, this cache may become out-of-synch with the list of active work items maintained by the Engine (for example, where another custom service has modified the status of a work item). The *Synchronise* icon (to the left of the refresh icon) allows administrators to re-synchronise the local cache with that of the Engine. The results of any changes brought about by re-synchronisation can be noted in the Tomcat log files. There are some system overheads involved with re-synchronisation, and it is rarely necessary, but may occasionally be of some benefit to long-running instances.

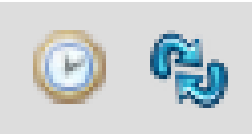


Figure 6.4: Admin Queue Tool Buttons (detail): Synch (left), Refresh (right)

Secondary Resources Administration

The *Secondary...* button on the *Admin Queues* form provides administrators with the ability to dynamically alter the set of secondary resources allocated to a work item, if the work item has not yet been started. This becomes especially important if the service has been configured to block the starting of work items on unavailable secondary resources (cf. Section 6.2). It is also possible to add secondary resources to a work item at runtime (before it starts) even if none were allocated to it at design time.

Clicking on the *Secondary...* button opens the *Secondary Resource Administration* dialog shown in Figure 6.5. This dialog has a similar layout to the 'Secondary Resources' panel of the Editor's Resource Wizard (cf. Section 4.11). On the left are lists of individual participants and their Roles, and individual 'assets' (i.e. non-human resources) and their categories. On the right is the list of selected secondary resources for the chosen work item. Selecting an item from a list on the left will move it to the list of selected resources on the right. Individual participants and assets can only be added once, but roles and categories may be added several times (as in the example of Figure 6.5, where the role "Surgical Nurse" has been chosen twice because two nurses are required for the work item).

ASIDE: Every non-human resource, or asset, belongs to a category. For example, a photocopier, a printer, a portable computer and a camera may all belong to the category "office machines". Categories may be further divided into a set of sub-categories, so for example, a photocopier may belong to the "copiers" sub-category, and a camera may belong to the "cameras" sub-category of the "office machines" category. Each category has a default sub-category called "None", into which all of the assets of the category that have not been explicitly sub-categorised are placed.

There are four buttons on the *Secondary Resource Administration* dialog:

- **Check**: This button will check the availability of each resource listed as a selected resource. A popup message dialog will list those resources that are currently unavailable, or a "success" message if all the selected resources are currently available.
- **Remove**: This button will remove the currently selected resource from the list of selected resources.
- **Save**: This button will save any changes made.

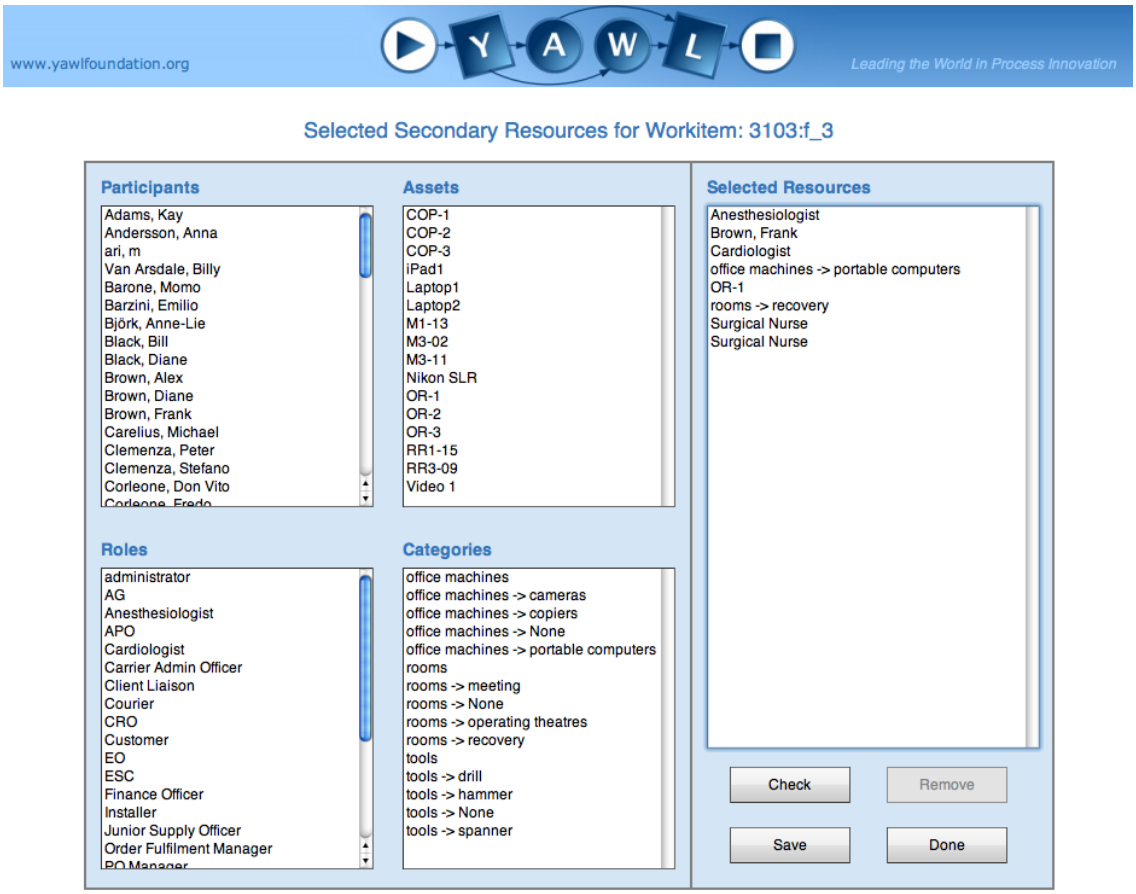


Figure 6.5: Secondary Resources dialog

- **Done**: Will close the dialog.

See Section **??** for more information about the management of non-human resources.

6.4.3 Service Management

The Service Management Screen can be used to add and to remove registered custom services. In the example in Figure 6.6, three services are already registered, the *SMS Service*, the *Worklet Service* and the *Web Service Invoker Service*.

A new service can be added by providing a name, a password and confirmation, a URI and a Description. The password and confirmation password must match each other, and name and password must also exactly match the credentials that will be used by the service to log onto the Engine (see Table 6.1 for a list of credentials for each of the standard YAWL custom services). The URI is validated by contacting it and waiting for an appropriate response, so care should be taken that the URI provided exactly matches that of the specified service.

Although the Resource Service itself is a custom service, it is *not* registered using this form, because it is pre-registered with the Engine as the *Default Worklist Handler* via a configuration setting.

The Editor, when connected to the Engine, will retrieve the set of registered services, and make them available for assigning to tasks by displaying the description entered for each service in the drop down list of the Task Decomposition dialog (see Section 4.6.3).

To deregister a service from the Engine, select it in the list, then click the *Remove* button.

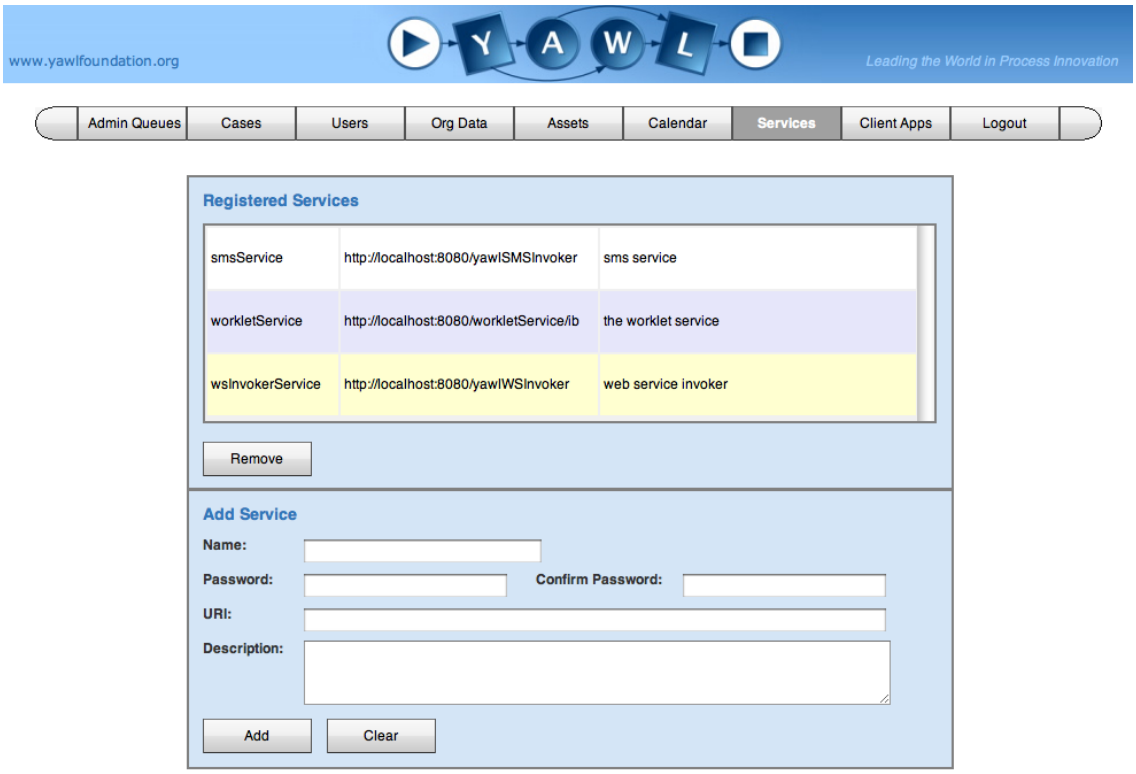


Figure 6.6: Service Management

Name	Password	URI
workletService	yWorklet	http://localhost:8080/workletService/ib
wsInvokerService	yWSInvoker	http://localhost:8080/yawlWSInvoker
smsService	ySMS	http://localhost:8080/yawlSMSInvoker
mailService	yMail	http://localhost:8080/mailService/ib
twitterService	yTwitter	http://localhost:8080/twitterService/ib
digitalSignatureService	yDigitalSignature	http://localhost:8080/digitalSignature/ib

Table 6.1: Logon Credentials and URIs for the Standard Custom Services

6.4.4 Client Application Management

Similar to the Service Management Screen, the Client Application Management Screen provides for the registration of logon credentials for external applications and services (i.e. non-custom services) that wish to connect to the Engine via its interfaces. Figure 6.7 shows and example of the Client Management Screen.

To add a new client application, provide a name, a password and confirmation, and a Description. The password and confirmation password must match each other, and name and password must also exactly match the credentials that will be used by the application to log onto the Engine. The credentials for the Editor are editor (username) and yEditor (password), and for the monitor service they are monitorService (username) and yMonitor (password).

Note that in Figure 6.7 the generic admin user id is also listed in the registered accounts. Its listing here allows administrators to change the password on the generic admin if desired. To change the password or description of a registered client application account, select it from the list then click the *Edit* button – the details of that account will populate fields on the lower half of the form, allowing you to modify and save them.

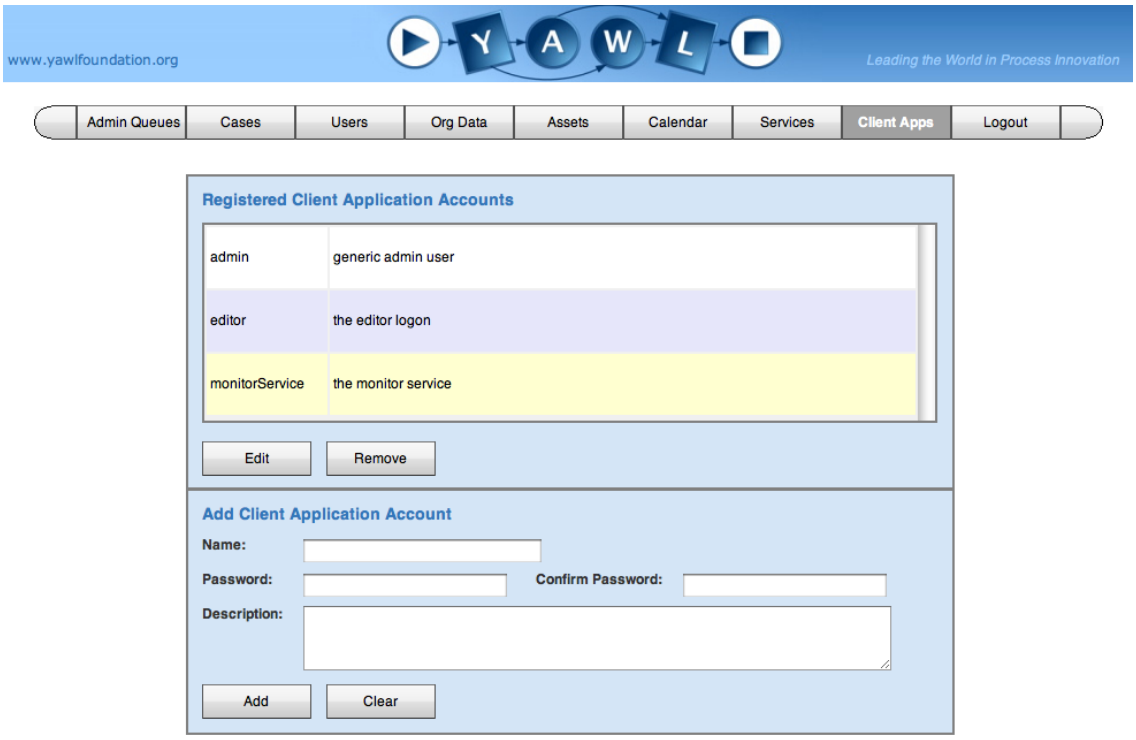


Figure 6.7: Client Application Management

To remove an account from the Engine, select it in the list, then click the *Remove* button. Note that the generic admin account cannot be removed in this way, but may be disabled via an Engine configuration setting (see Section 6.1).

ASIDE: The reason why the monitor service is listed as a client application and not as a custom service is simply because the monitor service does not qualify as a custom service. To qualify as a custom service, a service must be able to take responsibility for the execution of a task. That is, the service must be able to be assignable to a task at design time via the Editor's Task Decomposition dialog (as are all those services mentioned in Section 6.4.3). The monitor service can't be assigned tasks for execution, since it is designed to display information about current processes, and so rightly belongs in the list of client applications, as do all such services.

6.4.5 Managing Organisational Data

Roles, capabilities, positions and organisational groupings can be defined through the Org Data Mgt Screen, see Figure 6.8:

- **Role**: Generally, a role is a duty or set of duties that are performed by one or more participants. For example, bank teller, police constable, credit officer, auditor, properties manager and junior programmer are all examples of roles that may be carried out by one or more participants within an organisation. There may be several participants performing the same role (for example, a bank may have a number of tellers), so a typical role in an organisational model may contain a number of participants. Conversely, a certain participant may perform multiple roles. Further, a role may *belong to* a larger, more general role (for example, the roles junior teller and senior teller may both belong to a more general role called 'teller'). A role may be included in the distribution set for a task at design time, meaning that all of the participants performing that role (or any of its sub-roles) are to be considered as potential recipients of a work item created from the task at runtime.

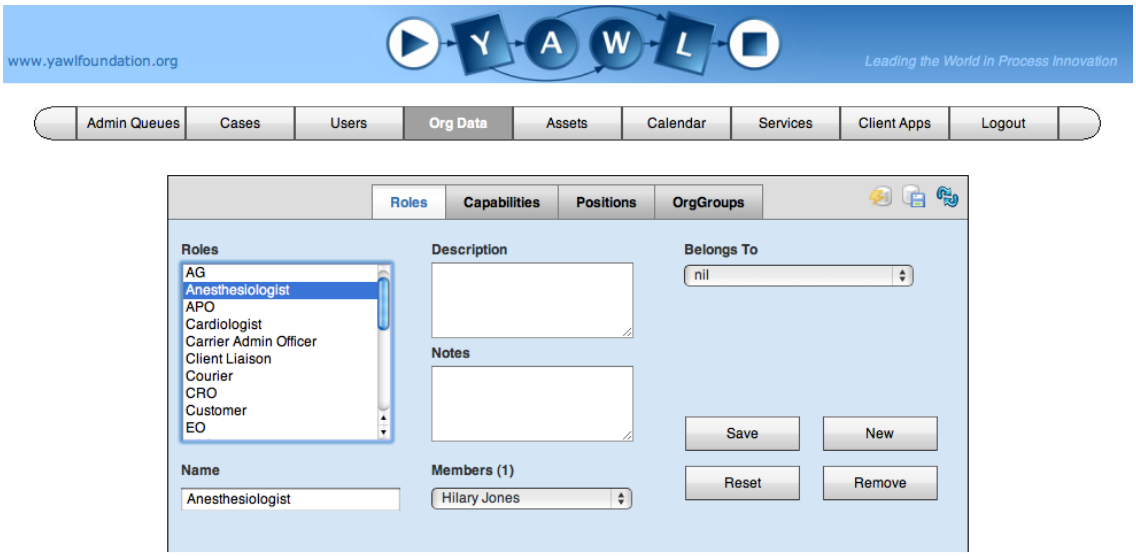


Figure 6.8: Organisational Data Management

- **Capability**: A capability is some desired skill or ability that a participant may possess. For example, first aid skills, health and safety training, a forklift license or a second language may all be considered as capabilities that a participant may possess that may be useful to an organisation. There may be several participants within an organisation possessing the same capability, and a certain participant may possess a number of capabilities. A capability (or capabilities) may be included in a filter defined at design time that is run over the distribution set for a task at runtime, so that only those participants within the distribution set that possess the specified capability or capabilities are potential recipients of a work item created from the task.
- **Position**: A position typically refers to a unique job within an organisation for the purposes of defining lines-of-reporting within the organisational model. Examples might include CEO or Bank Manager, or may be internal job codes (such as 'TEL0123'). A position may report to zero or one other positions (for example, bank teller 'TEL0123' may *report to* the Bank Manager), and may *belong to* zero or one Org Groups (see below). Like capabilities, a position (or positions) may be included in a filter defined at design time that is run over the distribution set for a task at runtime. Positions are also used at runtime to enable resource patterns such as delegation, reallocation and viewing of team work queues (see Section 6.7 for more details).
- **Org Group**: An organisational group (org group) is a functional grouping of positions. Common examples might include Marketing, Sales, Human Resources and so on, but may be any grouping relevant to an organisation. In the YAWL model, each position may *belong to* zero or one org groups. Further, like roles, an org group may *belong to* a larger, more general org group (for example, the groups Marketing and Sales may each belong to the more general Production group). Org groups are often also based on location. Like positions, org groups may be included in a filter defined at design time that is run over the distribution set for a task at runtime.

While the descriptions of the various entities in the YAWL model above discuss the typical uses of each, it should be clear that they represent, at the most basic level, merely various ways to group participants. The main point of distinction between them is that only roles can be used to populate a distribution set in the Editor, the other three may be used to perform filtering over the set.

The Org Data Screen contains four tab-pages, one for each of org entities listed above. The methods used to maintain the data for each entity is similar on each of these four pages:

- To **Add** a new entity, click the *New* button, which will display an 'Add New' input field. Enter a name

for the entity, and optionally a description and note, choose the entity it belongs to and/or reports to as required (see below), then click the *Add* button. You may cancel the addition at any time by clicking the *Reset* button instead of the *Add* button.

- To **Modify** an entity, select it from the list, then add or change its name, description, note, belongs to and/or reports to values, then click the *Save* button.
- To **Delete** an entity, select it from the list and click the *Remove* button.
- To view the list of participants that 'own' an entity, select it from the list. The *Members* dropdown shows all of the participants associated with the selected entity.

With regards to the *belongs to* and *reports to* relations:

- A role may belong to another role – you may set this relation using the *Belongs To* dropdown on the Roles tab-page. This allows a hierarchy of roles to be created, so that when a task is assigned to a role in the Editor, and that role has other roles belonging to it, those roles are also implicitly included (by inheritance). You will not be allowed to have a role belong it itself, either directly or as part of a cycle back to itself, for example if role A belongs to role B which in turn belongs to role C, you will not be allowed to have role C belonging to role A (or B).
- An org group can belong to another org group, similarly to a role. You may also set an *Group Type* for an org group via a dropdown; select the type of group from the list then click the *Save* button.
- A position may report to another position, allowing a lines-of-reporting hierarchy of positions to be created. Again, this is done in a similar fashion to setting a role *belongs to* hierarchy, and the same cyclical constraints apply. A position may also belong to an Org Group, which can be chosen via the Org Group dropdown on the Positions tab-page (Figure 6.9).

Figure 6.9: The Positions tab-page

To enable easy backup and recovery of organisational data, two tool buttons are provided on the top right of the tab panel. They may be seen in detail in Figure 6.10.

The button on the left is the *Import Org Data from File* button, and the button in the centre is the *Export Org Data to File* button (the third button refreshes the form in a similar way to the refresh button on other pages, as mentioned previously). To export your current set of org data, click on the *Export* button – a file

Figure 6.10: Org Data Form Tool Buttons

called 'YAWLOrgDataBackup.ybkp' will be created and downloaded via your browser. The file will contain your entire org database, including participants and non-human resources, in XML format (passwords are encrypted).

At any time, backed up org data can be re-imported by clicking on the *Import* button. You will be prompted for the file to import, via an *Import File* panel that will appear on the bottom of the form. Browse to the file, then click the *Import* button. Existing data is not removed – importing data will append new data and update existing data. A message describing the effects of the import will be displayed on completion.

6.4.6 Managing Users

Though the User Mgt Screen (see Figure 6.11), an administrator can add participants and change details and privileges for existing participants.

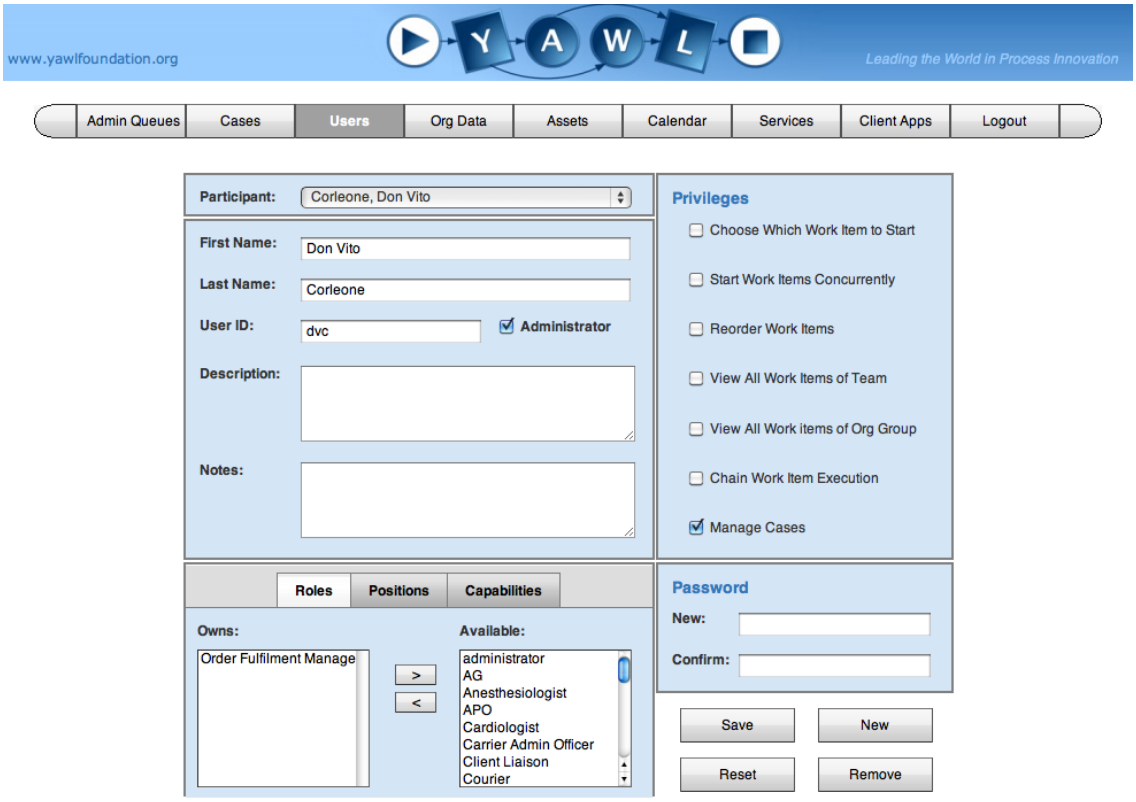


Figure 6.11: User Management

The User Mgt Screen consists of four panels: top-left shows the participant's personal details (name, password, userid and so on); top-right allows the setting of user privileges (see below); bottom-left allows the assigning of the participant to various roles, positions and capabilities; and bottom-right is where the participant's password can be reset. There are many similarities between the User Mgt and Org Data Mgt Screens regarding the addition, modification and removal of items:

- To **View** an existing participant's details, select the participant's name from the *Participant* dropdowm list.
- To **Add** a new participant, click the *New* button, which will disable the dropdown and activate all other fields. For a new participant, entries for first name, last name, userid and password (new and confirm) are required. Userids must begin with a character and may contain the letters, digits and underscores. Passwords must be at least 4 characters in length. The description, note and administrator fields are optional, as are privilege settings (by default all are unselected) and role/position/capability memberships. When you have finished adding participant information, click the *Add* button. You may cancel the addition at any time by clicking the *Reset* button instead of the *Add* button.
- To **Modify** a participant, select them from the list, then add or change the desired fields, then click the *Save* button.
- To **Delete** an participant, select them from the list and click the *Remove* button.

User Privileges

Primarily, each participant may be designated a 'user' (the default) or an 'administrator'. To grant administrator privileges for a participant, select the participant from the dropdown list, tick the *Administrator* checkbox, then click the *Save* button. Administrator privilege overrides all other user privileges. Participant's without administrator privileges may be granted specific privileges by selecting the participant from the dropdown list, then ticking the desired privileges, then clicking the *Save* button. The privileges that may be assigned to participants on an individual basis are:

- **Choose Which Work Item to Start**: When granted, this privilege allows a participant to choose any work item listed on their allocated queue to start. When denied (the default) only the first listed work item may be chosen. Work items are listed in order of age, with the oldest work item at the top of the list.
- **Start Work Items Concurrently**: When granted, this privilege allows a participant to have a number of work items executing concurrently on their started queue (or, more accurately, may choose to start additional work items from their allocated queue while other previously started work items have not yet completed). When denied (the default), a work item on the participant's allocated queue may not be started while there is a previously started work item on their start queue (i.e. one that has not yet completed).
- **Reorder Work Items**: When granted, the participant may choose a work item to start from anywhere in the list of allocated work items. When denied, only the first listed work item may be chosen. In the YAWL environment, there is essentially no difference between this privilege and *Choose Which Work Item to Start*.
- **View All Work Items of Team**: When granted, this privilege gives a participant access to the *Team Queues* form, and displays on that form a consolidated list of all work items on all work queues of all participants subordinate to the participant who has been granted the privilege (that is, participants holding positions that report to a position held by the granted participant, either directly or through a hierarchy of positions). When denied (the default), the *Team Queues* form is not available to the participant.
- **View All Work Items of Org Group**: When granted, this privilege gives a participant access to the *Team Queues* form, and displays on that form a consolidated list of all work items on all work queues of all participants in the same Org Group as the granted participant. When denied (the default), the *Team Queues* form is not available to the participant.
- **Chain Work Item Execution**: When granted, this privilege allows a participant to chain work items for a case. When denied (the default), the participant may not chain cases (see Section 6.7 for details regarding the chaining of tasks).

- **Manage Cases**: When granted, this privilege gives a participant access to the *Case Mgt* form, providing the ability to load process specifications, and start and cancel case instances. When denied (the default), the *Case Mgt* form is not available to the participant.

A participant with default user privileges (i.e. all unselected) have access to their own work queues, and may view/edit their own profile. A participant with *Manage Cases* privilege can also access the Case Mgt screen. A participant with *View All Work Items of Team* or *View All Work Items of Org Group* privilege can also access the Team Queues screen. All other screens can only be accessed by participants with administrator access.

6.4.7 Task Privileges

Task privileges (or, more precisely, *User-Task* privileges), unlike the *User* privileges described above, are set at design time via the Editor (see Chapter 4, Section 4.11) *on an individual task basis*. The relevant wizard panel is re-shown in Figure 6.12, and a description of each task privilege is included here for completeness.

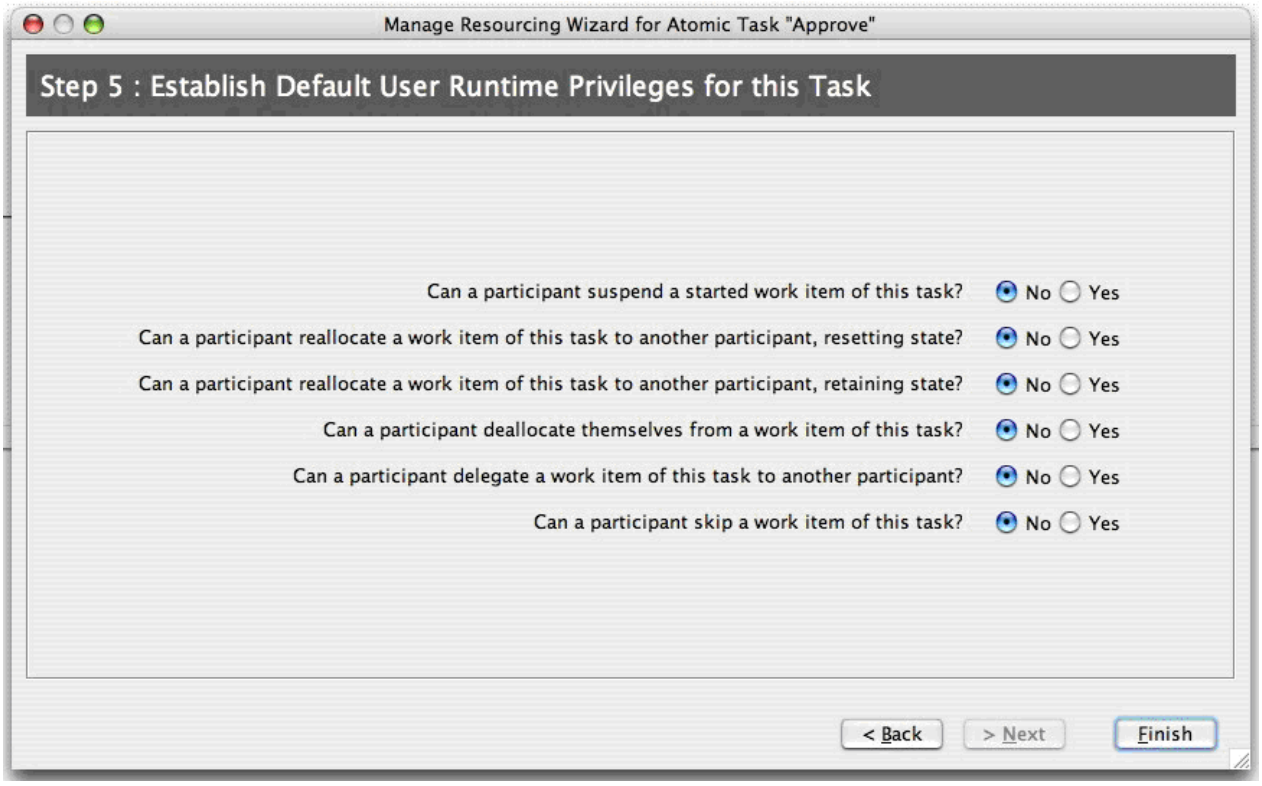

Manage Resourcing Wizard for Atomic Task "Approve"
Step 5 : Establish Default User Runtime Privileges for this Task
Can a participant suspend a started work item of this task? No Yes
Can a participant reallocate a work item of this task to another participant, resetting state? No Yes
Can a participant reallocate a work item of this task to another participant, retaining state? No Yes
Can a participant deallocate themselves from a work item of this task? No Yes
Can a participant delegate a work item of this task to another participant? No Yes
Can a participant skip a work item of this task? No Yes
< Back
> Next
Finish

Figure 6.12: Step 6 of the resource management wizard

Broadly speaking, task privileges grant or deny the ability to affect in various ways how work items are resourced after initial distribution has completed. There are seven task privileges:

- **Can Suspend**: When granted, allows a participant to suspend the execution of a work item after it has been started.

- **Can Reallocate Stateless**: When granted, allows a participant to transfer responsibility for the execution of a work item from themselves to another participant, with the data parameters of the work item reset to the values held when the work item was first started.

- **Can Reallocate Stateful**: When granted, allows a participant to transfer responsibility for the execution of a work item from themselves to another participant, with the data parameters of the work item having their current values maintained.
- **Can Deallocate**: When granted, allows a participant to reject or rollback the allocation of a work item to their allocated queue. The work item is redistributed using the original resourcing specification, but with the participant removed from the distribution set.
- **Can Delegate**: When granted, allows a participant to delegate the responsibility for the execution of a work item to a subordinate member of their work team, as defined by the organisational model.
- **Can Skip**: When granted, allows a participant to have the execution of a work item skipped – that is, immediately completed without performing its work.
- **Can Pile**: When granted, allows a participant to demand that all future instances of work items derived from this task, in all future instances of the specification of which the task is a member, are immediately directly routed to the participant and started.

All task privileges are denied by default, and so must be set explicitly for each task as required.

6.5 Managing Non-Human Resources

Similarly to the *Org Data Management* form, the *Asset Management* form allows administrators to add, modify and remove non-human resources and their categories. The form consists of two tabs, *Resources* and *Categories*, as can be seen in Figure 6.13.

Figure 6.13: Non-Human Resource Management (Resources tab)

- **Resources**: A non-human resource (or *asset*) is any organisational resource that isn't a person. Examples may include vehicles, meeting rooms, tools, raw materials, computers and other office equipment, and so on. Zero or more non-human resources may be allocated to a task, at design time and/or at runtime before the task is started, as so-called *secondary resources*. The set of allocated non-human resources represents those additional organisational resources that are required to perform the work of the work item. However, unlike the *primary resource*, they do not directly interact with the work list that the work item appears on. For example, in a hospital surgery setting, the primary resource for a

Schedule Surgery task may be a participant that belongs to the *Schedulers* role (only a participant can be a primary resource, and a task can have exactly one primary resource), while secondary resources for the task may include an operating theatre, a recovery room, sets of surgical instruments, a number of surgeons and surgical nurses (participants can be secondary resources, too) and so on.

- **Categories** A category is a grouping of non-human resources that relate to each other in some way. For example, a category called *Rooms* may include all of the usable rooms of an organisation that can be used in some way to perform an activity. A category may be further split into a number of sub-categories, for example the *Rooms* category in a hospital setting may include sub-categories such as *Meeting Rooms*, *Operating Theatres*, *Recovery Rooms*, *Lunch Rooms* and so on. A resource that is placed in a particular sub-category is also considered to be a member of its parent category (a room called 'M-123' in sub-category *Meeting Rooms* is also a member of category *Rooms*). Each resource therefore belongs to a single category and optionally a single sub-category within that category. Each category contains a 'special' sub-category called *None* which implicitly contains all the resources of the category that have not been explicitly placed into one of its sub-categories (for example, if the organisation has a single Conference room, there is little benefit creating a *Conference Rooms* sub-category for that one room).

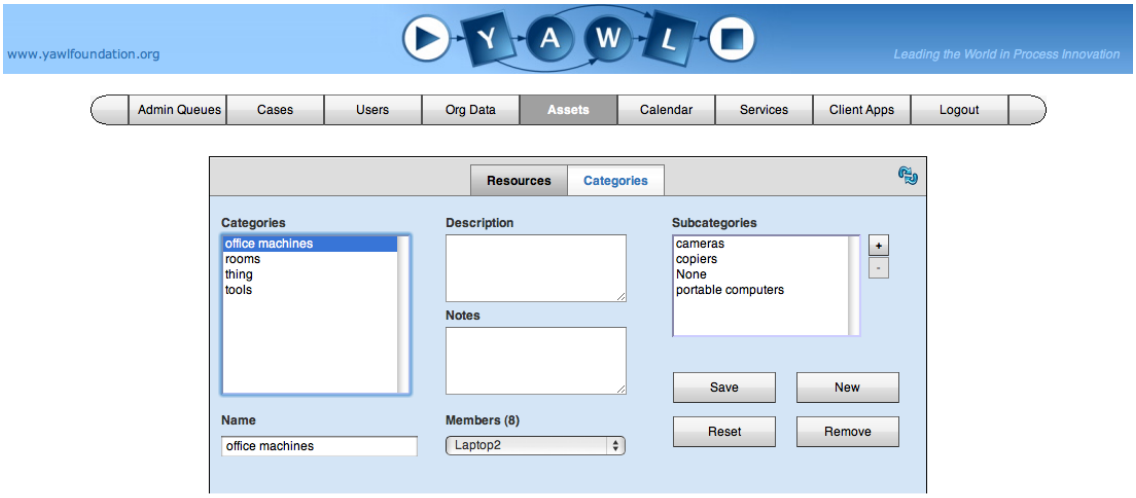


Figure 6.14: Non-Human Resource Management (Categories tab)

Of course, an organisation would include in its organisational model only those non-human resources that are limited in some way and are required exclusively to complete some activity. Also, how non-human resources are categorised is entirely subjective.

The **Resources** tab of the *Non-human Resources Management* form (Figure 6.13) is where individual non-human resources can be added, modified or removed.

- To **Add** a new non-human resource, first click the *New* button. Enter a name for the resource, and optionally a description and note, then choose the category it belongs to and optionally its sub-category, and finally click the *Add* button. You may cancel the addition at any time by clicking the *Reset* button instead of the *Add* button. Changing the selected category also changes the list of related sub-categories. If the resource does not have a sub-category, leave it set as 'None'.

- To **Modify** an non-human resource, select it from the list, then add or change its name, description, note, category and/or sub-category values, then click the *Save* button.

- To **Delete** an entity, select it from the list and click the *Remove* button.

On the **Categories** tab of the *Non-human Resources Management* form (Figure 6.14), categories and sub-categories can be added or removed, and member resources of each category can be viewed.

Categories can be added, updated and removed in the same way as non-human resources (on the *Resources* tab). To **add a sub-category** for the selected category, first click on the *Add Sub-category* button (the '+' button to the right of the sub-categories list), enter the name of the new sub-category in the input field that appears at the bottom of the list, then click the accept (tick) button to save it to the list, or the cancel (cross) button to cancel the addition (Figure 6.15). To **remove a sub-category** for the selected category, first select it then click on the *Remove Sub-category* button (the '−' button to the right of the sub-categories list). Note that the sub-category 'None' cannot be removed.

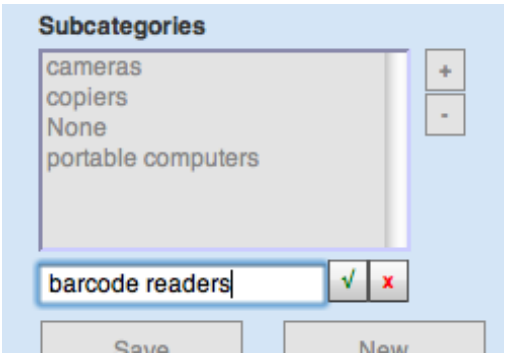


Figure 6.15: Non-Human Resource Management (Categories tab - detail)

6.6 Resource Calendar Management

As mentioned in the previous section, all of the resources (human and non-human, primary and secondary) allocated to a work item are marked as *in use* while the work item is executing, and are *released* when it completes. This means that while a resource is in use, it is unavailable to other work items that it may also have been allocated to. However, there may be other reasons why a resource is not available, even if it is not currently engaged in the performance of a work item. For example, a participant may be on annual leave, or away sick, or a particular machine may be offline for maintenance, and so on. To allow these periods of unavailability to be recorded and taken into account, a resource calendar is maintained by the Resource Service. The *Resource Calendar Management* form is shown in Figure 6.16. On this form, calendar entries for resources may be viewed, added, modified and removed. An entry in the calendar denotes that the specified resource is *unavailable* for the specified period.

At the top left of the form there is a date selector; choose a particular date to view entries for that date. Clicking the calendar button will display a calendar component from which a particular date may be selected. Clicking the left arrow button will go to the previous day, while the right arrow button will go to the next day.

On the top right, there is a dropdown list called *Filter*, with the following selections:

- **Unfiltered**: All entries for all resources are listed for the selected date (as in Figure 6.16). Entries cannot be added in this mode (see below).
- **All Resources**: Allows you to add entries that apply to all resources, both human and non-human. Lists all the *All Resources* entries for the selected date.
- **All Participants**: Allows you to add entries that apply to all participants. Lists all the *All Participants* entries for the selected date.
- **All Assets**: Allows you to add entries that apply to all assets (i.e. non-human resources). Lists all the *All Assets* entries for the selected date.

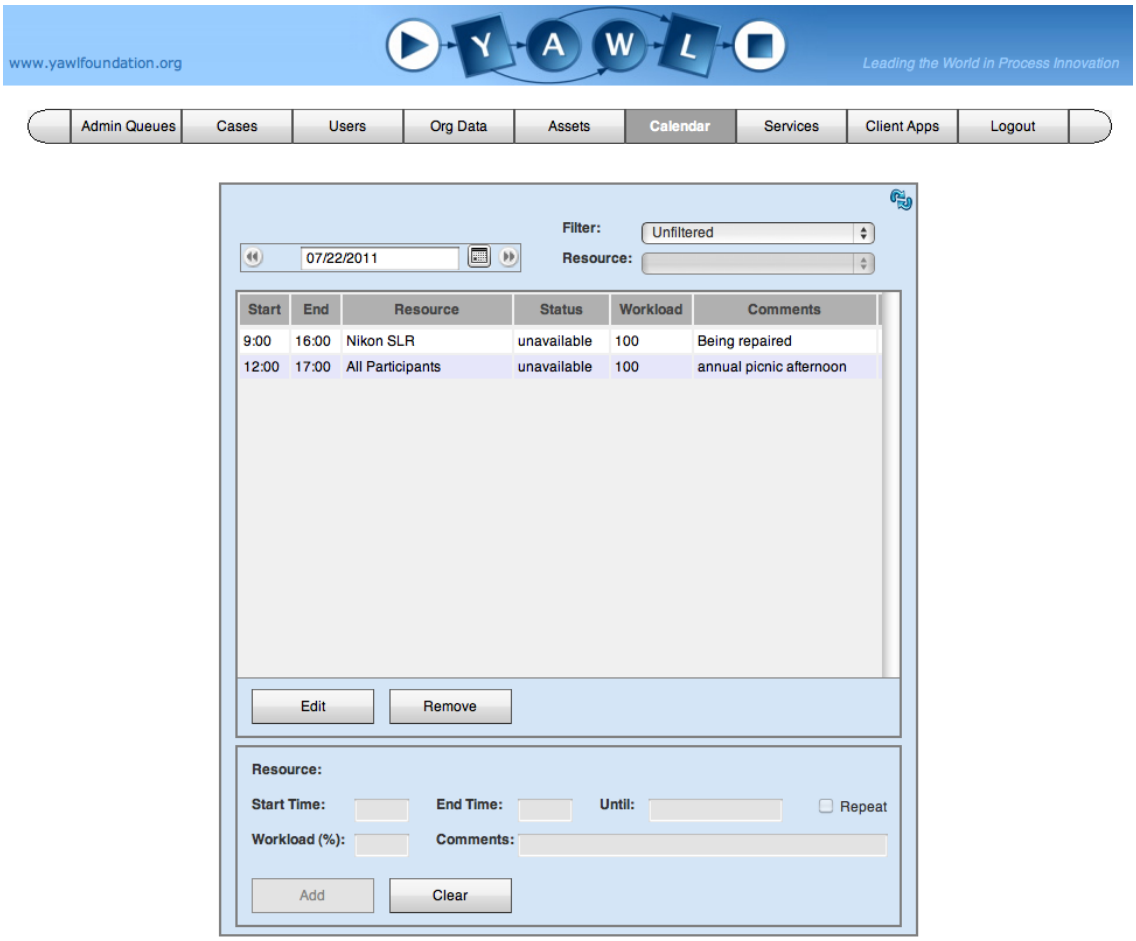


Figure 6.16: Resource Calendar Management Form

- **Selected Participant**: Enables the *Resource* dropdown list beneath it, and allows you to select an individual participant from that list. Once selected, all the existing entries for the participant for the selected date are listed, and allows new entries to be added for the participant.
- **Selected Asset**: Enables the *Resource* dropdown list beneath it, and allows you to select an individual asset from that list. Once selected, all the existing entries for the asset for the selected date are listed, and allows new entries to be added for the asset.

As mentioned above, calendar entries may be added that apply to All Resources (as a group), All Participants (as a group), All Assets (as a group), an individual participant or an individual asset. To **add** a new entry:

- Select the group or individual resource using the *Filter* and, if required, the *Resource* dropdowns. The name of the selected group or resource will be displayed on the bottom panel (for example, see Figure 6.17)
- Add the *Start Time* and *End Time* that the group or resource will be unavailable for. Times are entered in 24 hour format (h:mm), for example 9:00 or 16:45. If a time has zero minutes, the minutes part can be omitted (e.g. 9:00 can be entered as 9). Note that the start and end time fields are the only fields that are mandatory.
- (Optional) In the *Until* field, add the end date that the group or resource will be unavailable for. An entry in this field denotes that the group or resource will be unavailable from the date selected on the

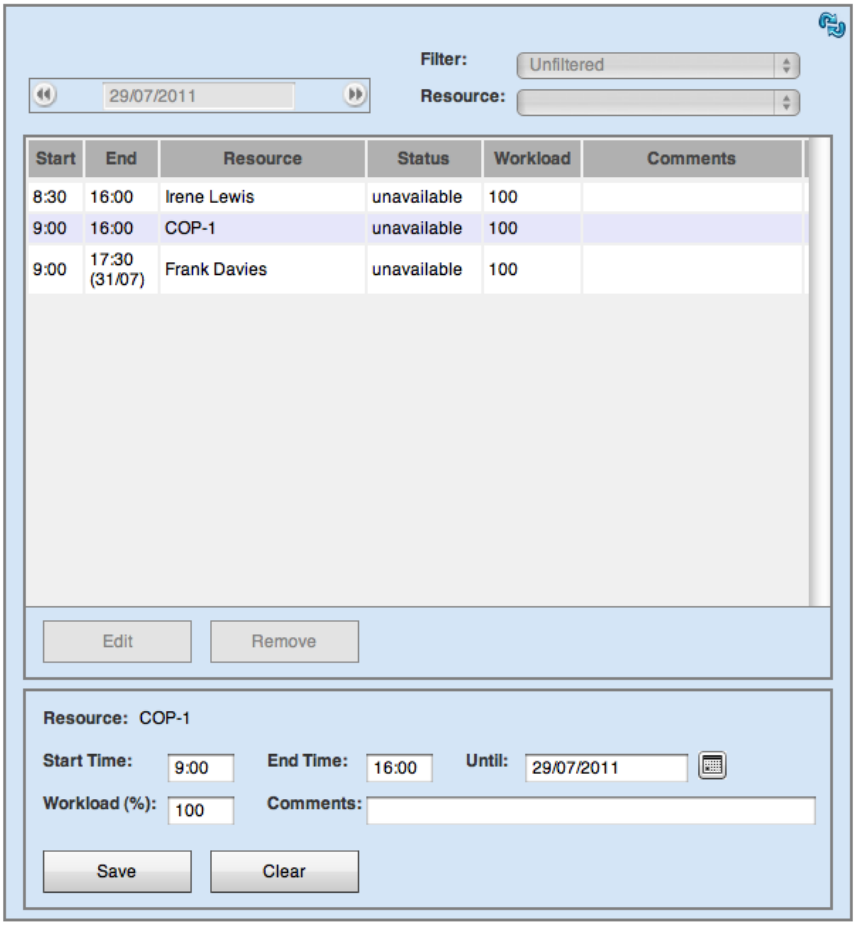


Figure 6.17: Resource Calendar Management – Editing an entry

top left of the form *until* the date selected in the *Until* field. Entries spanning more than a single day will show the start and end date in addition to the start and end time. If this field is left blank, the entry will apply only for the selected date.

- (Optional) Check the *Repeat* checkbox to denote a certain block of time each day across a range of dates. If it is unchecked, the entry will span a continuous block from the start date (selected at top-left of the form) and start time, until the end date (specified in the *Until* field)) and end time. If it is checked, a number of entries will be added, each one spanning from the specified start time to the specified end time, one entry for each date in the range of dates specified. For example, in Figure 6.17, the entry for Irene Lewis was added with an 'until' date entered and 'repeat' checked, and so she is marked as unavailable from 8:30–16:00 for each day in the date ranged entered, while the entry for Frank Davies was added without 'repeat' checked, which means he is unavailable for one continuous period from 29/07/2011 at 9:00 until 31/07/2011 at 17:30. Whether *Repeat* is checked or not is only relevant if an *Until* date has also been specified.

- (Optional) Enter a percentage workload amount (between 1-100) in the *Workload* field. A workload of less than 100 means the resource will only be partially unavailable for the specified period. For example, a value of 75 means that the resource may also be allocated as a secondary resource to a task at the same time, if that task only requires 25% of the output of that resource — that is, the resource can be shared across two or more tasks during the same period (an example may be a part-time worker, or a surgical nurse who can work between two operating theatres at the same time). If this field is leaft blank, it will default to 100%.

- (Optional) Enter a comment which explains why the group or resource is unavailable for the period.

To **edit** an entry, select it from those listed and click the *Edit* button. The entry's values will be copied to the relevant fields in the bottom panel. Edit the values as desired, then click the *Save* button the save the changes, or the *Clear* button to reject the changes and return to view mode. If an entry spans more than one day, you must select the first day of the span before you can edit it (a warning message will be displayed if there is an attempt to edit a multi-date entry that is not positioned on its start date).

Finally, to **remove** an entry, select it from the list then click the *Remove* button.

6.7 Work Queues

Work items have an associated life cycle and when interacting with the Resource Service it is important to understand the various stages that a work item can go through. An overview (not complete, but sufficient for our purposes) of the life-cycle of a work item is shown in Figure 6.18. The labels of the arcs correspond to the names of buttons that users of the Resource Service can click on to effect the state change.

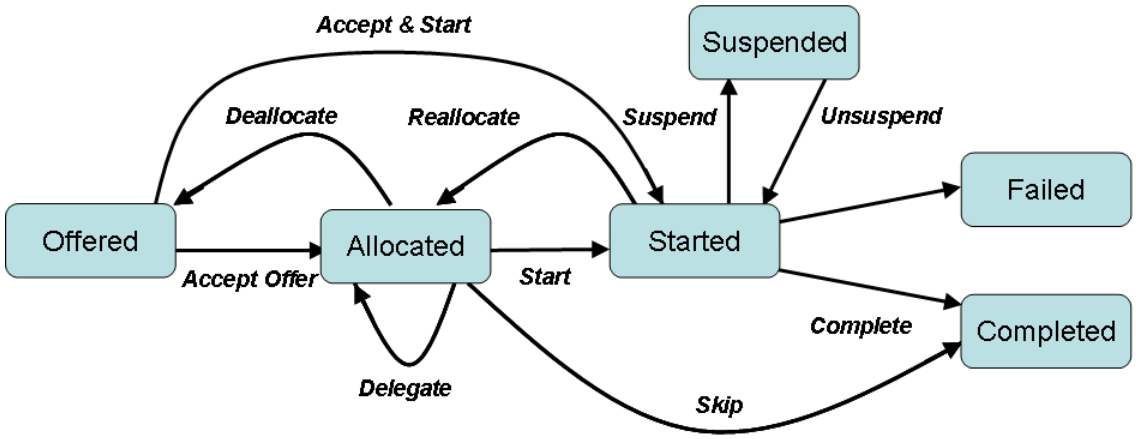


Figure 6.18: Part of the Life-cycle of a Work Item

Each participant has access to their own work queues, which are collectively known as a *worklist* – a graphical representation of their work queues via a series of web forms. Each worklist consists of four work queues: *Offered*, *Allocated*, *Started* and *Suspended*. Depending on a participant's privileges, there are a number of actions that can be performed on a work item in each queue. Some are concerned with processing the work item, while others provide for changes to the work item's resourcing.

The layout of each work queue is similar (see for example Figure 6.19).

- On the left is a list of the work items currently held in that queue.
- In the centre are some fields that describe the currently selected work item. The *Age* field, which shows how long it is since the work item was first created, changes to an *Expires In* field for timed work items (i.e. how long the work item has before its timer expires).
- On the right are a set of buttons representing the actions that may or may not be taken (depending on privileges) on that queue for the currently selected work item.
- At the bottom of each work queue is a *Documentation* field. If documentation was assigned to the task at design time, it will appear here at runtime. Additionally, the field is editable, so that documentation may be added at runtime. The following macros may be embedded in the documentation:
  - now - insert the current date and time

- $date$ - insert the current date
- $time$ - insert the current time

An administrator may add documentation for a work item via the admin work queues and it will be immediately viewable on the queues of those participants who have that work item listed, and vice versa.

Each work queue may be selected by clicking on the appropriate tab.

6.7.1 The Offered Queue

The Offered queue lists the work items that have been offered to a participant. Each work item in an offered queue may have potentially been offered to a number of participants, which means there is no implied obligation to accept the offer, rather it is understood that the participant is one of a group, any one of who *may* choose to perform the work item.

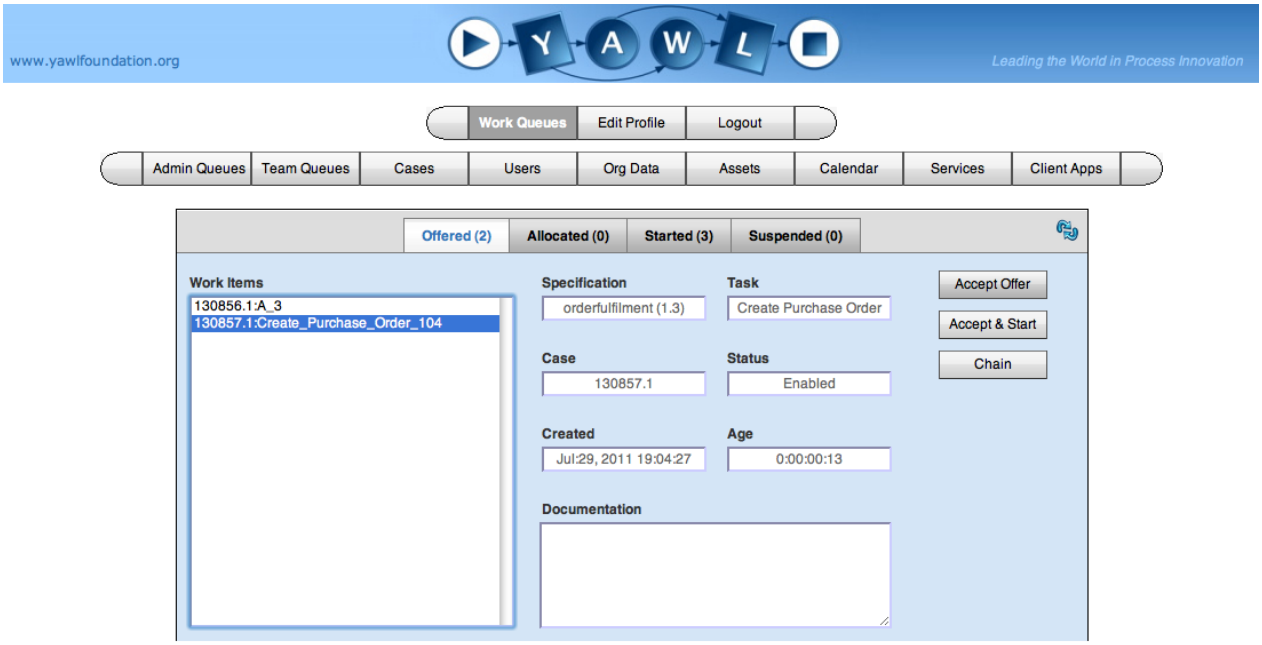


Figure 6.19: The Offered Work Queue

A participant may take the following actions on a work item in an offered queue:

- **Accept Offer**: By accepting an offer, a participant takes responsibility for the execution of the work item. The work item is moved from the offered queue and, if the start interaction is user-initiated, placed on the participant's allocated queue, or if the start interaction is system-initiated, the work item is immediately started and placed on the participant's started queue. This action removes the work item from the offered queues of all other participants that had been previously offered the work item.
- **Accept & Start**: This action works similarly to *Accept Offer*, except that if the work item's start interaction is user-initiated, the work item will instead be immediately started and placed on the participant's started queue. Effectively, this concatenates two user actions into one, simply as a convenience for the user.
- **Chain**: This action will chain all the eligible work items of the case of which the work item is a member to this participant. Chaining means that, when a participant chooses to enact it, each remaining work

item for the case is routed to the participant and immediately started, but *only* if the participant is a member of the distribution set for the work item. Chaining is effectively a short-circuiting of a resource specification for a task, where the participant chooses to automatically and immediately allocate and start any work item offered to him/her within the chosen case. Chaining of work items for a case continues until the case completes, or the participant turns off chaining via the *View Profile* form. A participant must have the "Chain Work Item Execution" user privilege to enable chaining.

6.7.2 The Allocated Queue

The Allocated queue lists the work items that have been allocated to a participant. Unlike an offer, a work item on an allocated queue means that it has been allocated to that participant alone, and comes with the understanding that the participant will at some time start the work item and perform its work.

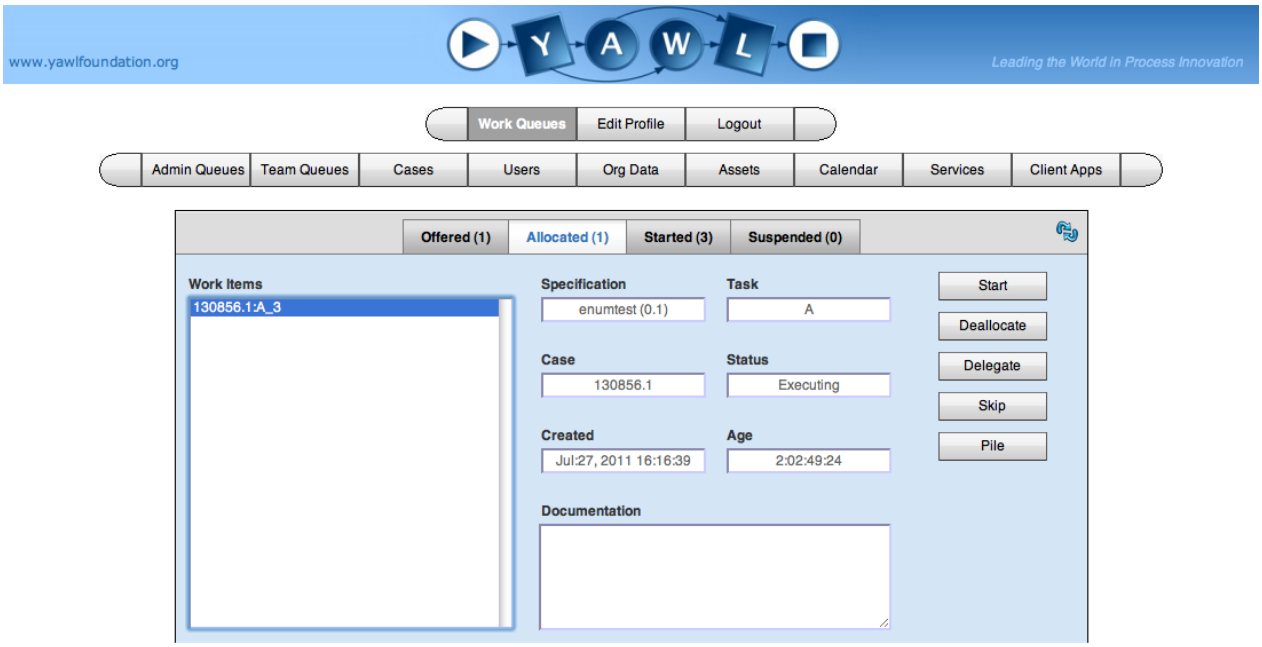


Figure 6.20: The Allocated Work Queue

A participant may take the following actions on a work item in an allocated queue:

- **Start**: The work item is started (i.e. begins executing), and moved to the participant's started queue.
- **Deallocate**: This action provides an authorised participant with a means of rejecting a work item that has been allocated to them. The work item is removed from the participant's allocated queue, the participant is removed from the original distribution set and the work item is redistributed as per the resourcing specification for the task. A participant must have the task privilege "Can Deallocate" to enable deallocation.
- **Delegate**: This action allows a participant to delegate responsibility for a work-item to another participant. The receiving participant must be subordinate to the delegating participant by Position. The work item is moved from the allocated queue of the delegator to the allocated queue of the receiver. A participant must have the task privilege "Can Delegate" and have subordinate staff to successfully deallocate a work item.
- **Skip**: This action skips the execution of the work item – that is, the work item is immediately started and then completed, allowing the process to continue according to its subsequent control-flow. A participant must have the task privilege "Can Skip" to enable the skipping of a work item.

- **Pile**: When a work item is piled, the work item is immediately started and placed in the participant's started queue. Furthermore, *each and every future instance of the work item across all cases of the same specification* is automatically allocated to the participant and started, completely ignoring any resourcing specification for the task from which the work item is created. To put it another way, by piling a work item, a participant is entering into a contract with the Resource Service, asking that this work item, and all future occurrences of such work items created from the same task description as the original work item was created from, be immediately allocated and started to him/her. Piling of such work items continues until the participant turns off piling for the task via the *View Profile* form, or the participant logs out (if so configured). A participant must have the "Can Pile' task privilege to enable piling.

6.7.3 The Started Queue

The Started queue lists the work items that have been started by or for a participant. Each work item on a started queue has begun execution in a system sense, but may or may not have had any actual work begun for it by the participant—such work is performed by the participant viewing, editing and finally completing the work item.

Figure 6.21: The Started Work Queue

A participant may take the following actions on a work item in an started queue:

- **View/Edit**: This action will display the data parameters and their current values for the selected work item, either on a dynamically generated form (see Figure 6.22) or, if specified, a custom form, allowing the participant to view and/or edit the form's values. Any modified values are stored so that this action can be repeated for a particular work item a number of times before completion, allowing the work item to be processed by the participant in a progressive manner, if required. This action is disabled if the work item has no data parameters to display or gather values for.

- **Suspend**: This action suspends the selected work item. The work item is removed from the started queue and placed on the participant's suspended queue. A participant must have the task privilege "Can Suspend" to successfully suspend a work item.

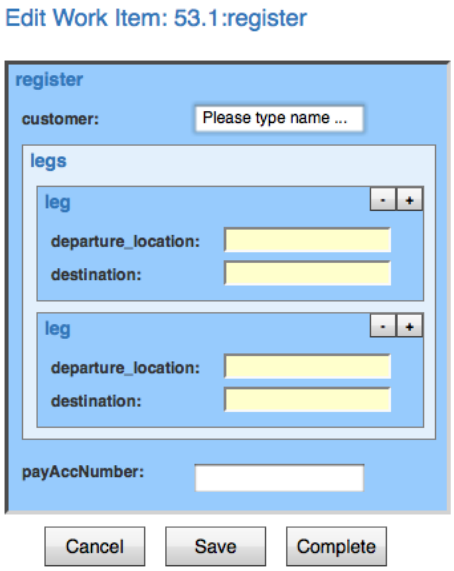


Figure 6.22: An Example of a Dynamically Generated Form

- **Reallocate Stateless**: This action allows a participant to reallocate a work item to another participant. The receiving participant must be subordinate to the reallocating participant by Position. The work item's data values are reset to the values that existed when the work item was first started (i.e. stateless reallocation), and it is moved from the started queue of the reallocator to the *started* queue of the receiver. A participant must have the task privilege "Can Reallocate Stateless" and have subordinate staff to successfully reallocate a work item.

- **Reallocate Stateful**: Similar to "Reallocate Stateless", except that any modified data values are maintained when the work item is reallocated. A participant must have the task privilege "Can Reallocate Stateful" and have subordinate staff to successfully reallocate a work item.

- **New Instance**: This action allows for the creation of a new instance of the selected work item; it is enabled only for a work item of a multiple instance atomic task that allows dynamic creation of additional work item instances.

- **Complete**: Completes the selected work item. The work item is posted back to the engine, which then progresses the case according to its control-flow. This action is initially disabled if the work item contains mandatory editable data variables (as in Figure 6.21), and becomes enabled after the first view/edit of the work item.

6.7.4 The Suspended Queue

The Suspended queue lists executing work items that have been suspended via the *Suspend* button on the Started queue. Note that suspended work items must have already been started and not yet completed, and so this queue may be seen as an extension of the started queue. This queue contains one action, **Unsuspend**, which resumes the work item, removing it from the suspended queue and returning it to the started queue.

6.8 User Profiles

The *Edit Profile* screen consists of four panels (Figure 6.24):

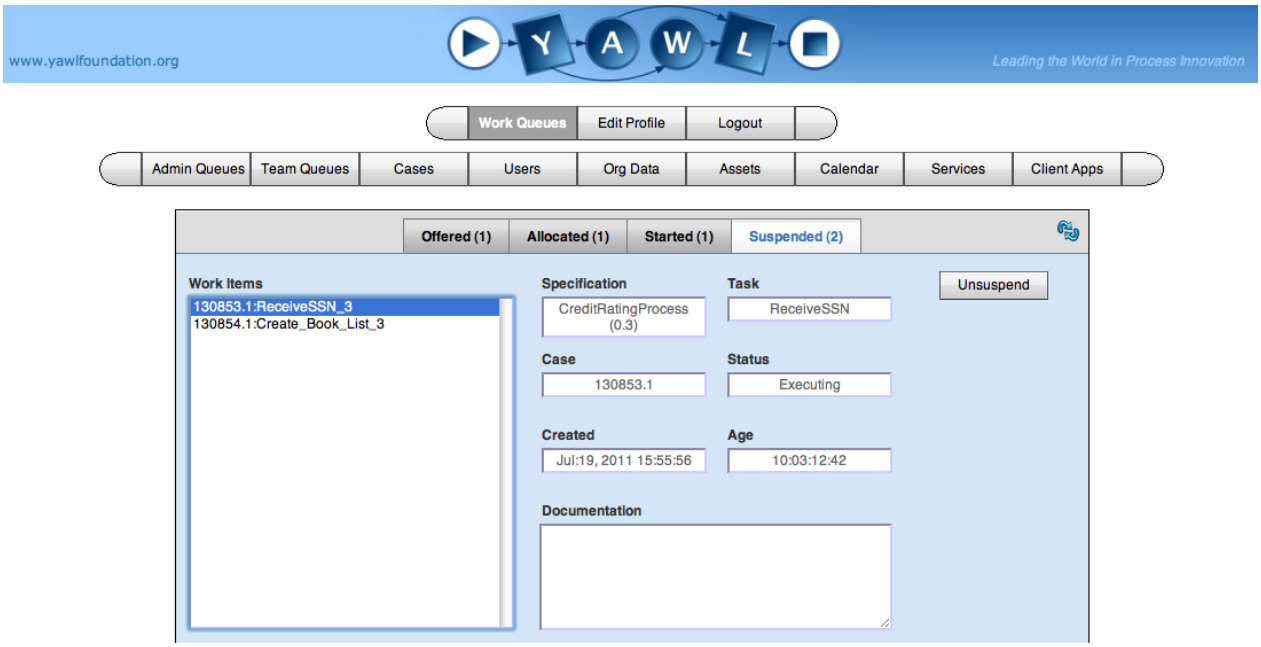


Figure 6.23: The Suspended Work Queue

- A *Personal Information* panel, where a participant can see their name, userid, lists of their roles, positions and capabilities, and whether he/she has administrator privileges. All of this information is read-only.

- A *Change Password* panel, where the participant may change their password. Passwords must be at least 4 characters in length, and the 'New' and 'Confirm' entries must match.

- A *Piled Tasks* panel, where all of the tasks that are currently piled to the participant are listed. The participant may choose to cease the piling of a task to them by selecting it from the list and clicking the 'Unpile' button.

- A *Chained Cases* panel, where all of the cases currently chained to the participant are listed. The participant may choose to cease the chaining of a case to them by selecting it from the list and clicking the 'Unchain' button.

6.9 Team Queues

The *Team Queues* screen shows groups of active work items in a single list. There are two types of groupings possible:

- A participant who has been granted the user privilege 'View All Work Items of Team' may view a list of all the active work items that appear on the work queues of all the participants who are subordinate to them by Position. For example, in Figure 6.25 the participant listed holds the position 'CD clerk', which reports to the position of the currently logged on participant, 'Head of CD'.

- A participant who has been granted the user privilege 'View All Work Items of Org Group' may view a list of all the active work items that appear on the work queues of all the participants that are members of the same Org Group as the logged on participant.

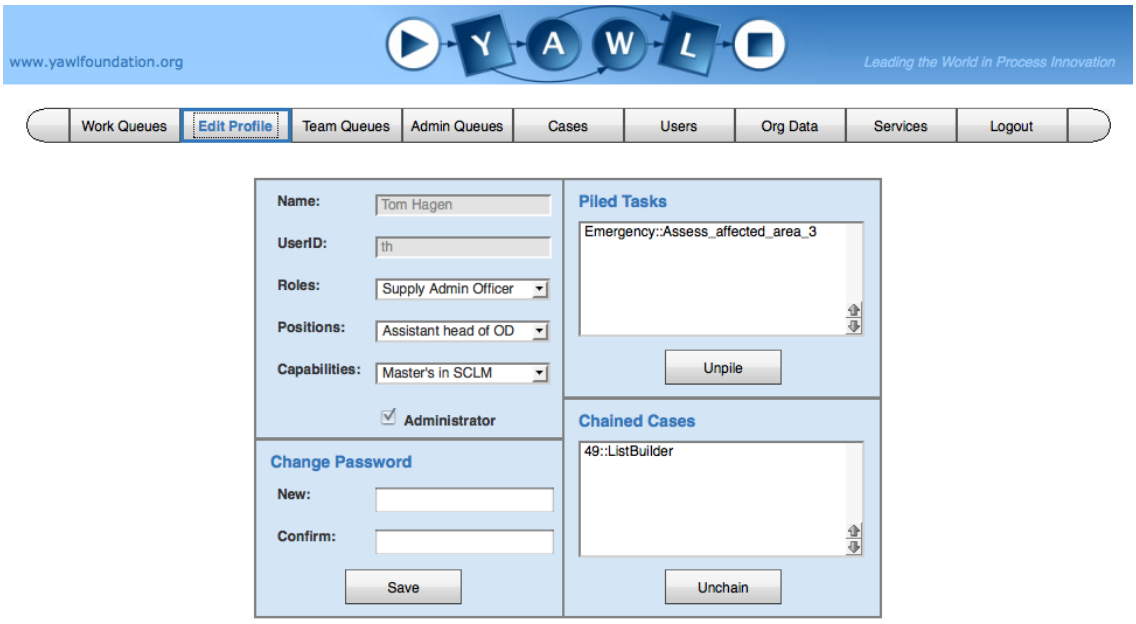


Figure 6.24: The Edit Profile Screen

Figure 6.25: The Team Queues Screen

All of the information displayed on this screen is read-only. A participant who has been granted both privileges may switch between views using the radio buttons to the right of the form; if they have been granted one of the two privileges, the other choice is disabled.

6.10 YAWL Worklist iGoogle Gadget

A simplified version of the YAWL worklist is offered as an iGoogle Gadget, so that users can see the workitems currently in their work queues as a 'live feed', along with the information in the other gadgets

they may have enabled on their iGoogle page.

6.10.1 Setting up the Worklist Gadget

The first step in setting up the gadget is to create a personal iGoogle page. To do so, browse to Google, then click the *iGoogle* link in the top right corner of the page. If you have not yet done so, you will be asked to create an account.

When you have your iGoogle page loaded, click on the *Add gadgets* link on the right of the page header. You will see a page with a list of popular gadgets to choose for your page (you must be connected to the internet to access an iGoogle gadget). To load the 'YAWL Worklist' gadget:

1. Click the *Add feed or gadget* link on the bottom of the list of links on the left frame of the page (under 'Sort By' and 'Narrow by Category' link lists).
2. In the input box that appears (Figure 6.26) enter the URL: `http://www.yawlfoundation.org/gadgets/igYWorklist.xml`
3. Click the *Add* button.
4. Click *OK* on the warning dialog that appears.

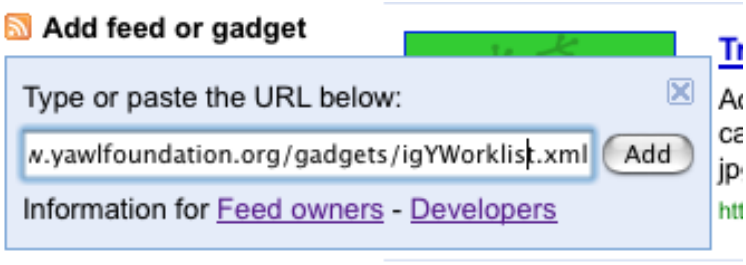


Figure 6.26: Adding the Worklist Gadget to an iGoogle Page

When you go back to the iGoogle home page, the YAWL Worklist should appear (Figure 6.27), but before it can be used, some settings must be entered for it (click the 'down-arrow' button on the right of the YAWL gadget's title bar, then select *Edit Settings* from the context menu that appears):

- **UserID** *(required)*: A valid YAWL user account id;
- **Password** *(required)*: The password for the nominated YAWL account. Note that the password is retained as plain text, so please ensure you log out of iGoogle before anyone else uses the same computer.
- **YAWL Base URI** *(required)*: The URI of the Tomcat container running the YAWL Resource Service that will recognise the userid and password entered. The YAWL URI may be local (on the current computer) or remote (accessible via the internet).
- **Name** *(optional)*: Any text entered here will display on the titlebar of the gadget, after the 'YAWL Worklist:' title.
- **Alt Tab Names** *(optional)*: By default, the names shown in the worklist's tabs for each queue are 'Offered', 'Allocated', 'Started' and 'Suspended'. Choosing the *Alt Tab Names* option will instead show them as 'Available', 'Assigned', 'In Progress' and 'Suspended'.
- **Show Suspended** *(optional)*: If this option is unselected the 'Suspended' queue will be hidden. Note that, due to the width limits of iGoogle gadgets, when the 'Suspended' queue is shown, the number of work items in each queue cannot be displayed with the tab title.

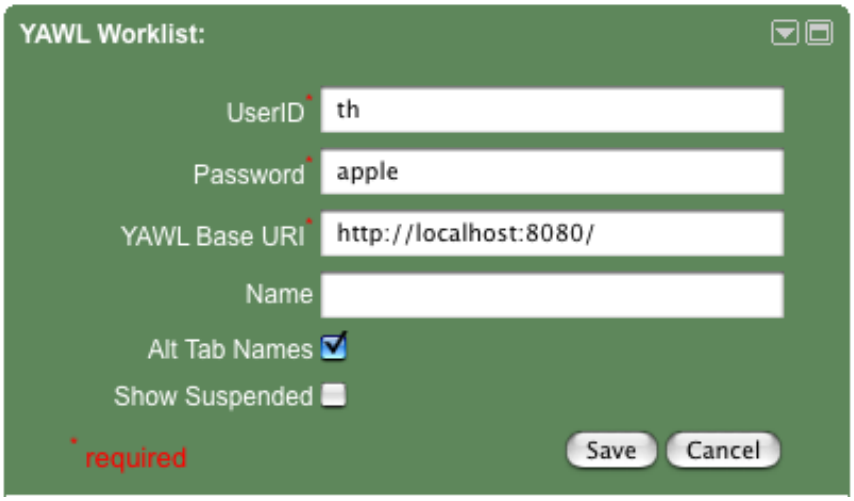


Figure 6.27: The Worklist Gadget's Settings dialog

Click the *Save* button to save your settings. If they are valid, you will see a worklist something like the one in Figure 6.28. You can modify these settings at any time by clicking on the dropdown menu on the top-right of the gadget's titlebar (the small button with the dropdown arrow) and choosing *Edit Settings*.

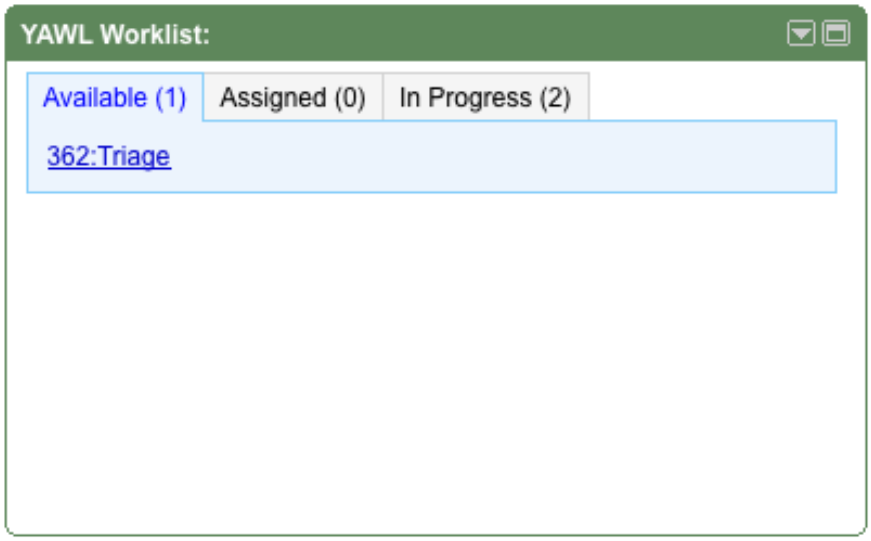


Figure 6.28: The Worklist Gadget

6.10.2 Using the Worklist Gadget

Each queue shows the work items available to the user, specified as hyperlinks. When you click on a work item link in *any* queue, the data form for the work item will display on a new tab or window (depending on browser settings). That is, when a work item link is clicked:

- If the work item is on the Offered (Available) queue, it is immediately allocated to the user and started, then its form is displayed;
- If the work item is on the Allocated (Assigned) queue, it is immediately started, then its form is displayed;

- If the work item is on the Started (In Progress) queue, its form is displayed;
- If the work item is on the Suspended queue, it is immediately unsuspended, then its form is displayed.

Just as it is for the default worklist handler of the Resource Service, if the work item was associated with a custom form at design time, then the custom form will display; if not, then a dynamically generated form will appear. You do not have to be logged on to YAWL before you click on a work item link in the gadget.

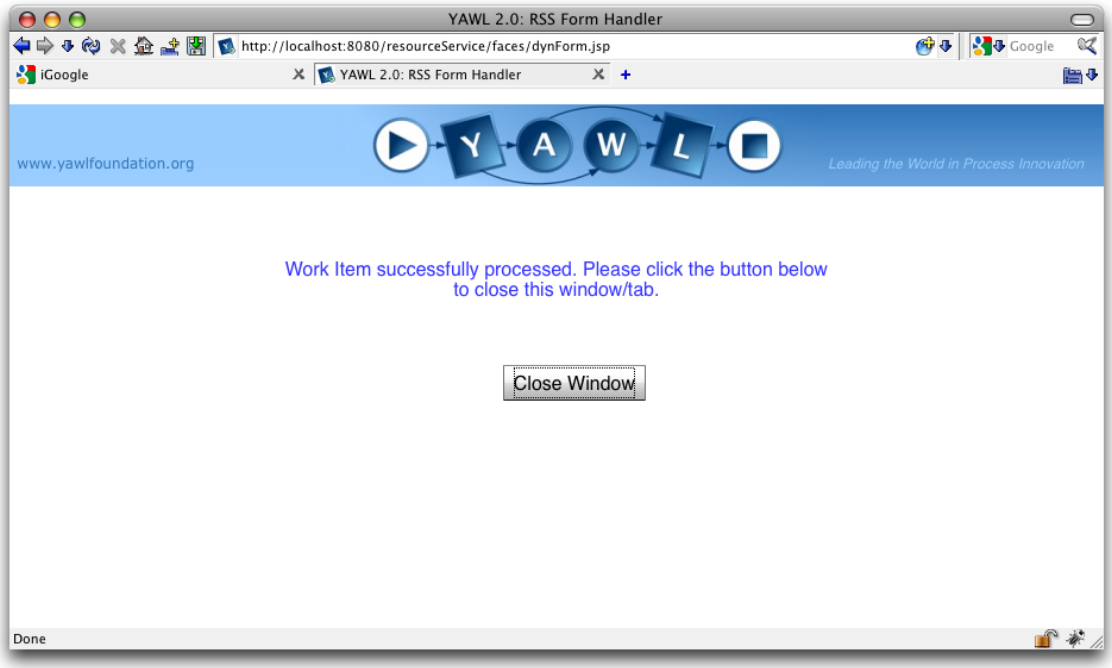


Figure 6.29: The Worklist Gadget's Post-Form-Display Message

When you leave the form (whether by a Cancel, Save or Complete action) a message will appear on the page informing of the success or otherwise of the action taken (Figure 6.29). Note that your current logon status is unaffected by actions you take on the gadget – if you were already logged on to YAWL in another tab or window, that session will remain active after the action completes; if you were not already logged on, you will automatically be logged on to enable the processing of the work item, then logged out again when the processing completes. Close this page to return to the iGoogle tab/window, and refresh the iGoogle page to show any newly available work items or queue changes caused by your actioning of the work item.

Chapter 7

The Monitor Service

The Monitor Service is a basic service that provides a summary view of all currently active cases within the YAWL engine. It consists of three screens that are viewed hierarchically – the case level, the workitem level and the parameter level.

7.1 Installation and Logging On

To install the Monitor Service:

1. Copy the file *monitorService.war* to your tomcat/webapps directory, and wait for it to fully unpack.
2. Go to the Client Applications web form, and register an account for the Monitor Service with these credentials:
   - **username**: monitorService
   - **password**: yMonitor
   - **description**: The YAWL Monitor Service

To log onto the Monitor Service, put the following URL in a browser: `http://localhost:8080/monitorService` (see Figure 7.1). The logon form has a green background to differentiate it from the Resource Service logon form. Any participant registered via the resource service that has administration privileges, or the generic 'admin' account (if enabled), can be used to logon to the Monitor Service.

7.2 Active Cases

The Active Cases form lists all of the currently executing case instances. Figure 7.2 shows an example.

In common with the other Monitor Service forms, the Active Cases form consists of a header, an information bar and a table. Inside the header are buttons (reading from the right) to refresh the page contents and to immediately logoff. In the table, clicking on a column heading will sort the contents on that column, alternating between ascending and descending order. The information bar for the Active Cases form shows a date and time of the last Engine (re)start.

The Active Cases table has columns for the case id, specification name, specification version and the data/-time the case began. A single click on any Active Case table row will show the work item detail for that case instance on the following form.

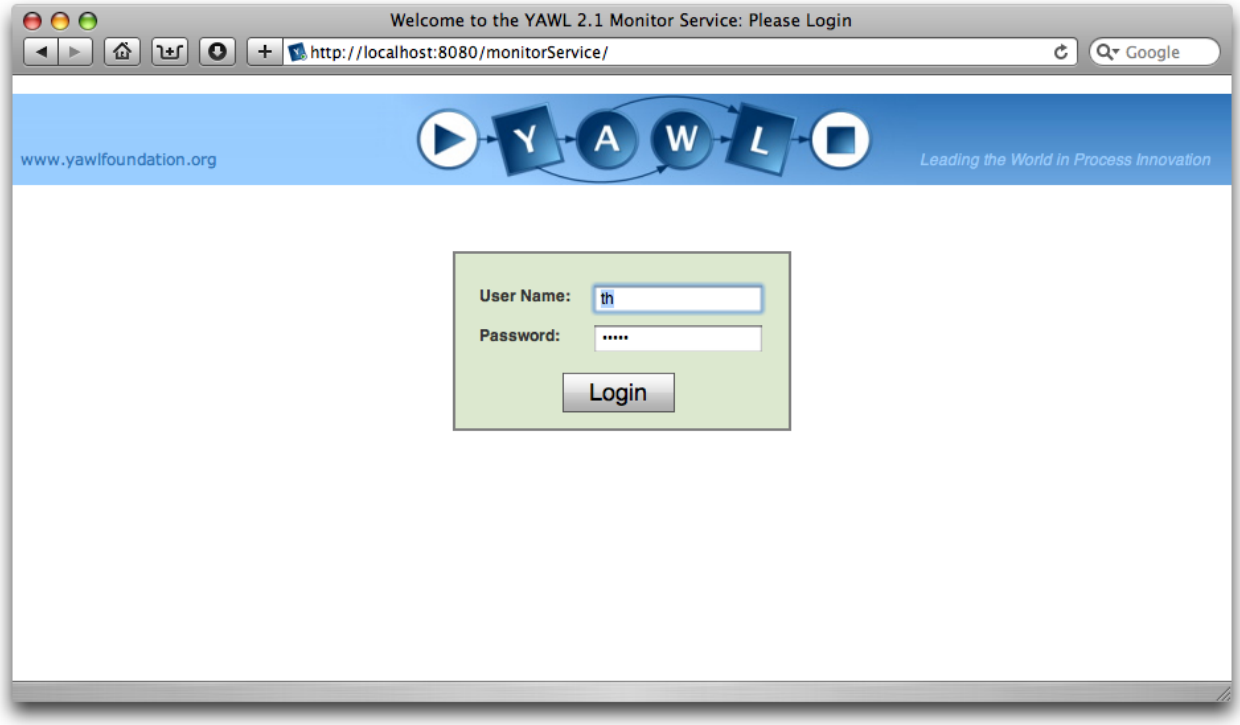
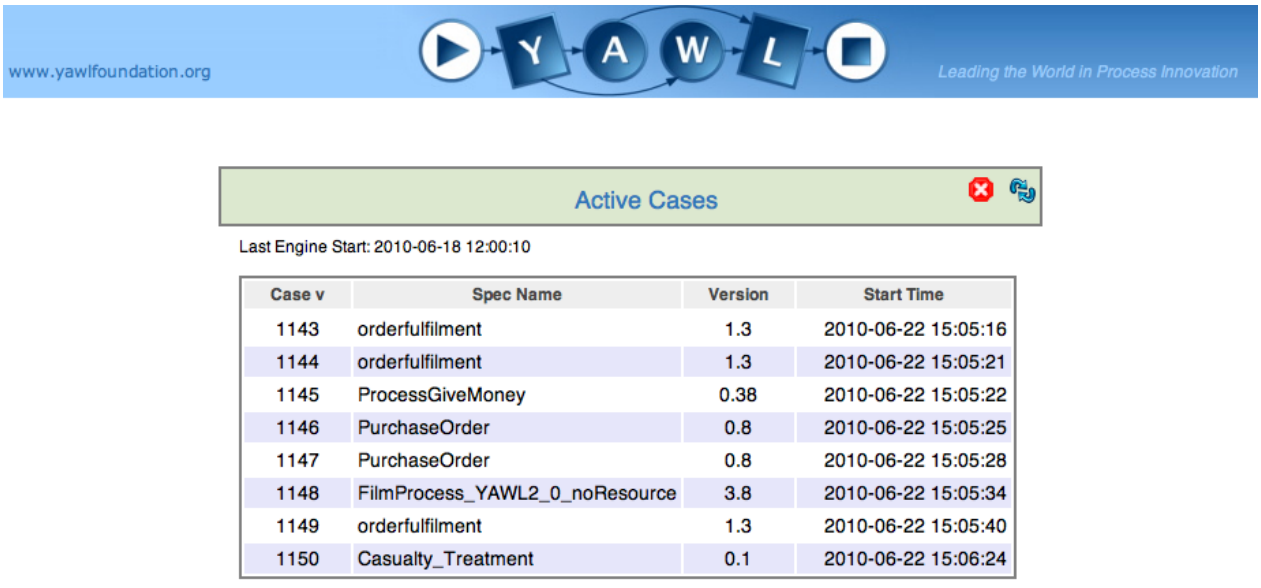


Figure 7.1: The Monitor Service logon screen



Case v	Spec Name	Version	Start Time
1143	orderfulfilment	1.3	2010-06-22 15:05:16
1144	orderfulfilment	1.3	2010-06-22 15:05:21
1145	ProcessGiveMoney	0.38	2010-06-22 15:05:22
1146	PurchaseOrder	0.8	2010-06-22 15:05:25
1147	PurchaseOrder	0.8	2010-06-22 15:05:28
1148	FilmProcess_YAWL2_0_noResource	3.8	2010-06-22 15:05:34
1149	orderfulfilment	1.3	2010-06-22 15:05:40
1150	Casualty_Treatment	0.1	2010-06-22 15:06:24

Figure 7.2: The Monitor Service Active Cases form

7.3 Work Items

Figure 7.3 shows an example of the Work Items of Selected Case form. The structure is similar to the Active Cases Form, but with the additional detail:

- a button on the left of the header bar for returning to the Active Cases form

- the information bar, containing the data/time of the case start, the service that started the workitem (in this example, the 'DefaultWorklist' – that is, the Resource Service), the participant who started the workitem, and the current case-level data (as XML).
- a table of workitems created by the case instance, with columns case id, task id, current status, starting service, enabled time, started time, completed time, timer status (if any) and timer expiry time (if applicable).

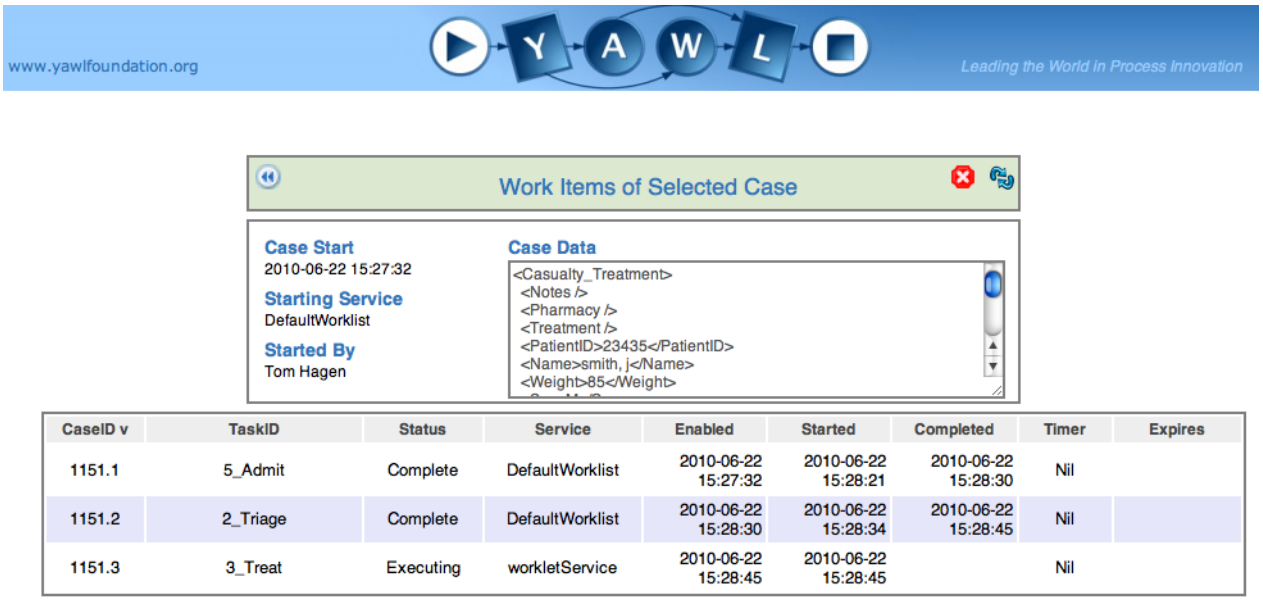


Figure 7.3: The Monitor Service Work Items of Selected Case form

Note that *all* work items for the case are listed, both currently active and those that have already completed. Also notice in this example that the first two tasks were started by the Resource Service, but the third by the Worklet Service (since that task is mapped to the worklet service at design time. A single click on a table row will show the associated parameters for that workitem.

7.4 Parameters

Figure 7.4 shows an example of the Parameters od Selected Work Item form:

- the information bar contains a list of logged events associated with this workitem from both the engine and the resource service (where applicable)
- the table shows all the parameters defined for the workitem, with columns name, data type, data schema (complex type definitions are listed here when used), the parameter's usage type (inputOnly, inputOutput, outputOnly), input and output mapping expressions (as applicable) and the input, default and last values.

Note that the current version of the monitor service does not support data persistence. That is, any information stored about completed items is lost if the Engine is restarted. This represents the initial release of the monitor service and it is envisaged that its functionality will grow in future versions.

Parameters of Selected Work Item

Engine Log Events

Resource Log Events

2010-06-22T15:28:21.563+1000	allocate	Tom Hagen
2010-06-22T15:28:22.261+1000	start	Tom Hagen
2010-06-22T15:28:30.200+1000	complete	Tom Hagen

Name v	DataType	DataSchema	Usage	Input Pred.	Output Pred.	Orig. Value	Def. Value	Value
Age	long	long	inputOutput	{number(/Casualty_Treatment/Age/text())}	{number(/Admit/Age/text())}	21		21
DiastolicBP	long	long	inputOutput	{number(/Casualty_Treatment/DiastolicBP/text())}	{number(/Admit/DiastolicBP/text())}	80		80
HeartRate	long	long	inputOutput	{number(/Casualty_Treatment/HeartRate/text())}	{number(/Admit/HeartRate/text())}	72		72
Height	double	double	inputOutput	{number(/Casualty_Treatment/Height/text())}	{number(/Admit/Height/text())}	1.8		1.8
Name	string	string	inputOnly	{/Casualty_Treatment/Name/text()}		smith, j		smith, j
PatientID	string	string	inputOnly	{/Casualty_Treatment/PatientID/text()}		23435		23435
Sex	string	string	inputOutput	{/Casualty_Treatment/Sex/text()}	{/Admit/Sex/text()}	M		M
SystolicBP	long	long	inputOutput	{number(/Casualty_Treatment/SystolicBP/text())}	{number(/Admit/SystolicBP/text())}	120		120
Weight	long	long	inputOutput	{number(/Casualty_Treatment/Weight/text())}	{number(/Admit/Weight/text())}	85		85

Figure 7.4: The Monitor Service Parameters of Selected Work Items form

Chapter 8

The Worklet Service

This chapter contains instructions for installing and using the *Worklet Dynamic Process Selection & Exception Handling Custom Service for YAWL*.

Each section describes one part in the process of setting up and using the Worklet Service. It is probably best to work through the manual from start to finish the first time it is read. This manual focuses on the practical use of the Worklet Service. For those interested, a more technical description of the inner operations of worklets and the rule sets that support them can be found in the technical manual. A more concise version of the worklets approach can be found in [9], while a more concise version of the exlets approach can be found in [8]. The ultimate reference on worklets and exlets is Michael Adams' PhD thesis [7]. All these publications can be downloaded from `www.yawlfoundation.org`.

All of the example specifications, rule sets, and so on referred to in this manual can be found in the "worklet repository" distributed with the service as part of the YAWL 2.2 release.

This icon indicates a hands-on method or instruction.

8.1 What is a Custom YAWL Service?

An important point of extensibility of the YAWL system is its support for interconnecting external applications and services with the workflow execution engine using a service-oriented approach. This enables running workflow instances and external applications to interact with each other in order to delegate work, to signal the creation of process instances and workitems, or to notify a certain event or a change of status of existing workitems.

Custom YAWL services are external applications that interact with the YAWL engine through XML/HTTP messages via certain endpoints, some located on the YAWL engine side and others on the service side. Custom YAWL services are registered with the YAWL engine by specifying their location, in the form of a "base URL". Once registered, a custom service may send and receive XML messages to and from the engine. More specifically, Custom YAWL services are able to check-out and check-in workitems from the YAWL engine. They receive a message when an item is enabled, and therefore can be checked out. When the Custom YAWL service is finished with the item it can check it back in, in which case the engine will set the work item to be completed, and proceed with the execution.

8.1.1 What is the YAWL Worklet Service?

The *Worklet Dynamic Process Selection & Exception Handling Service* for YAWL comprises two distinct but complementary services: a Selection Service, which enables dynamic flexibility for YAWL process instances; and an Exception Handling Service, which provides facilities to handle both expected and unexpected process exceptions (i.e. events and occurrences that may happen during the life of a process instance that are

not explicitly modelled within the process) at runtime. A brief introduction to each Service follows.

8.1.2 The Selection Service

The Worklet Dynamic Process Selection Service (or *Selection Service*) enables flexibility by providing a process designer with the ability to substitute a workitem in a YAWL process at runtime with a dynamically selected "worklet" - a discrete YAWL process that acts as a sub-net for the workitem and so handles one specific task in a larger, composite process activity. The worklet is dynamically selected and invoked and may be created at any time, unlike a static sub-process that must be defined at the same time as, and remains a static part of, the main process model.

An extensible repertoire (or catalogue) of worklets is maintained by the Service. Each time the Service is invoked for a workitem, a choice is made from the repertoire based on the contextual data values within the workitem, using an extensible set of rules to determine the most appropriate substitution.

The workitem is checked out of the YAWL engine, and then the selected worklet is launched as a separate case. The data inputs of the original workitem are mapped to the inputs of the worklet. When the worklet has completed, its output data is mapped back to the original workitem, which is then checked back into the engine, allowing the original process to continue. Worklets can be substituted for atomic tasks and multiple-instance atomic tasks. In the case of multiple-instance tasks, a worklet is launched for each child workitem. Because each child workitem may contain different data, the worklets that substitute for them are individually selected, and so may all be different.

The repertoire of worklets can be added to at any time, as can the rules base used for the selection process. Thus the service provides for dynamic ad-hoc change and process evolution, without having to resort to off-system intervention and/or system downtime, or modification of the original process specification.

8.1.3 The Exception Service

During every instance of a workflow process, certain things happen "off-plan". That is, it doesn't matter how much detail has been built into the process model, certain events occur during execution that affect the work being carried out, but were not defined as part of the process model. Typically, these events are handled "off-system" so that processing may continue. In some cases, the process model will be modified to capture this unforeseen event, which involves an organisational cost (downtime, remodelling, testing and so on).

The Worklet Dynamic Exception Handling Service (or *Exception Service*) provides the ability to handle these events in a number of ways and have the process continue unhindered. Additionally, once an unexpected exception is handled a certain way, that method automatically becomes an implicit part of the process specification for all future instances of the process, which provides for continuous evolution of the process but avoiding the need to modify the original process definition.

The Exception Service uses the same repertoire of worklets and dynamic rules approach as the Selection Service. The difference is that, while the Selection Service is invoked for certain tasks in a YAWL process, the Exception Service, when enabled, is invoked for every case and task executed by the YAWL engine, and will detect and handle up to ten different kinds of process exception. As part of the handling process, a process designer may choose from various actions (such as cancelling, suspending, restarting and so on) and apply them at a workitem, case and/or specification level.

The Exception Service is extremely flexible and multi-faceted, and allows a designer to provide tailor-made solutions to runtime process exceptions, as described in the following pages.

8.2 Installation

8.2.1 Worklet Installation Package

The Worklet Service is distributed as a standard component of the YAWL environment, and so is included in each of the various installer packages, and the **YAWL2.2_CoreWebServices.zip** file used for manual installations. Specifically, the service is contained in the file **workletService.war** - this is the worklet web application component. When unpacked, *workletService.war* also contains the **worklet repository**, a required set of directories where worklets and rules files are stored, logs are written to and so on, and a number of sample worklets and rule sets (including all those discussed in this manual) are located.

The structure of the repository is shown in Figure 8.1.

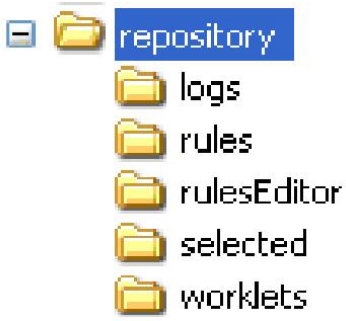


Figure 8.1: Worklet Repository Folder Structure

- The *logs* folder is where the Service writes certain log files during its operation. In particular, the *eventLog.csv* file logs the key events of the service (when database persistence is disabled). All are plain text files.
- The *rules* folder contains the sets of rules used during the selection and exception handling processes. Rules files have an XML format. Each YAWL specification that uses the service will have a corresponding rules file of the same name, except with an extension of *xrs* (XML rule set).
- The *rulesEditor* folder contains a tool that is used to manage and modify rule sets (see Section 8.5.2 for a complete description of the Rules Editor).
- The *selected folder* contains a set of files, in XML format, that are essentially log files that capture the results of each selection process (either via the Selection Service, or through the selection of a compensating worklet via the Exception Service). These files have an *xws* extension (XML Worklet Selection). These files are used by the Rules Editor to enable the addition of new rules for a specification.
- The *worklets* folder contains the worklet specification files. These files are YAWL specifications that are run as required by the service.

Several of the folders contain examples.

8.2.2 Configuring the Worklet Service

Manual Installs Only: The *workletService.war* file should be located in the *webapps* directory of your Tomcat installation (if necessary, refer to Chapter 2, Section 2.4 for more information). Then, the file needs to be extracted to its own directory under *webapps*. The easiest way to achieve this is to simply start Tomcat - it will automatically extract, install and start the Worklet Service.

Once the service is fully extracted and installed, there are a couple of minor configuration tasks to complete.

Open the Worklet Service's *web.xml* file (in folder \webapps\workletService\WEB-INF\) in any text editor.

By default, the worklet repository is located within the service's own file structures. However, you may change the location of the repository if you wish. Locate the parameter named *Repository*, and change its *param-value* to the path where you have relocated the worklet repository. The value should include the folder 'repository' and end with a slash, as shown in Figure 8.2[1].

```
<context-param>
   <param-name>Repository</param-name>
   <param-value>
       ${catalina.base}\webapps\workletService\repository\
   </param-value>
   <description>
      The path where the worklet repository is installed.
   </description>
</context-param>

<context-param>
   <param-name>EnablePersistence</param-name>
   <param-value>false</param-value>
   <description>
      'true' to enable persistence and logging
      'false' to disable
   </description>
</context-param>
```

Figure 8.2: The Worklet Service's *web.xml* file (detail)

If you have enabled database persistence for the YAWL Engine (if necessary, see Chapter 2, Section 2.4 for details about enabling persistence for the YAWL Engine), then persistence should also be enabled for the Worklet Service (so that case data for running processes can be persisted across Tomcat sessions). To enable persistence, change the *param-value* to **true** for the *EnablePersistence* parameter.

Save and close *web.xml*. Worklet Service configuration is now complete. However, by default the Selection Service is enabled within the YAWL Engine, but the Exception Service is not. If you wish to enable the Exception Service, proceed to Step 3 below.

Enabling the Worklet Exception Service

When YAWL 2.2 is installed, the Exception Service is configured as disabled. To enable the Exception Service, a parameter has to be set in its *web.xml* file.

Open the Worklet Service's *web.xml* file (in folder *webapps**workletService*\WEB-INF*\). Locate the parameter named *EnableExceptionHandling*; to enable the Exception Service, change the *param-value* to **true** (see Figure 8.3). Save and close *web.xml*.

The Exception Service uses extensions (or 'hooks') in the YAWL default worklist handler (a component of the Resource Service) to provide methods for interacting with the Worklet Service, so if you have enabled the service as above, you also need to enable the extensions in the Resource Service.

To do so, locate and open the Resource Service's *web.xml* file (in folder *webapps**resourceService*\WEB-INF*\).

Locate the context parameter named *InterfaceX_BackEnd*. By default, the entire parameter block is commented out. To enable the Exception Service extensions to the worklist, simply remove the comment tags

[1] ${catalina.base} is an environment variable pointing to the path of your Tomcat installation.

```
<context-param>
    <param-name>EnableExceptionHandling</param-name>
    <param-value>false</param-value>
    <description>
        'true' to enable exception handling functionality
        'false' to disable
    </description>
</context-param>
```

Figure 8.3: The Worklet Service's *web.xml* file (detail)

(the "<!–" and "–>" surrounding the *context-param* block – see Figure 8.4 below). Save and close *web.xml*.

```
<!-- This param, when available, enables the worklet exception
     service add-ins to the worklist. If the exception service
     is enabled in the engine, then this param should also be
     made available. If it is disabled in the engine, the
     entire param should be commented out. -->
<!--
<context-param>
    <param-name>InterfaceX_BackEnd</param-name>
    <param-value>http://localhost:8080/workletService</param-value>
    <description>
        The URL location of the worklet exception service.
    </description>
</context-param>
-->
```

Figure 8.4: The Resource Service's *web.xml* file (detail)

The Exception Service is now fully enabled and operational. For information on how the Exception Service works and how to use it, see Sections 8.3 and 8.6.

Installing the Rules Editor

The Worklet Rules Editor allows you to browse the rule sets of specifications, add new rules to existing rule sets, and add complete, new rules trees to rule sets. It is a .NET based application, so has the following requirements:

- Operating System: Windows OSs 98SE or better
- The Microsoft .NET framework (any version). If you don't have the framework installed, it can be downloaded for free from Microsoft: http://www.microsoft.com/downloads.

The Rules Editor tool is found in the *rulesEditor* folder of the worklet repository. It can be executed directly from there - no further installation is required.

For more details on the Rules Editor and how to use it, refer to Section 8.5.2.

8.3 Using the Worklet Selection Service

Fundamentally, a worklet is nothing more than a workflow specification that has been designed to perform one part of larger or 'parent' specification. However, it differs from a decomposition or sub-net in that it

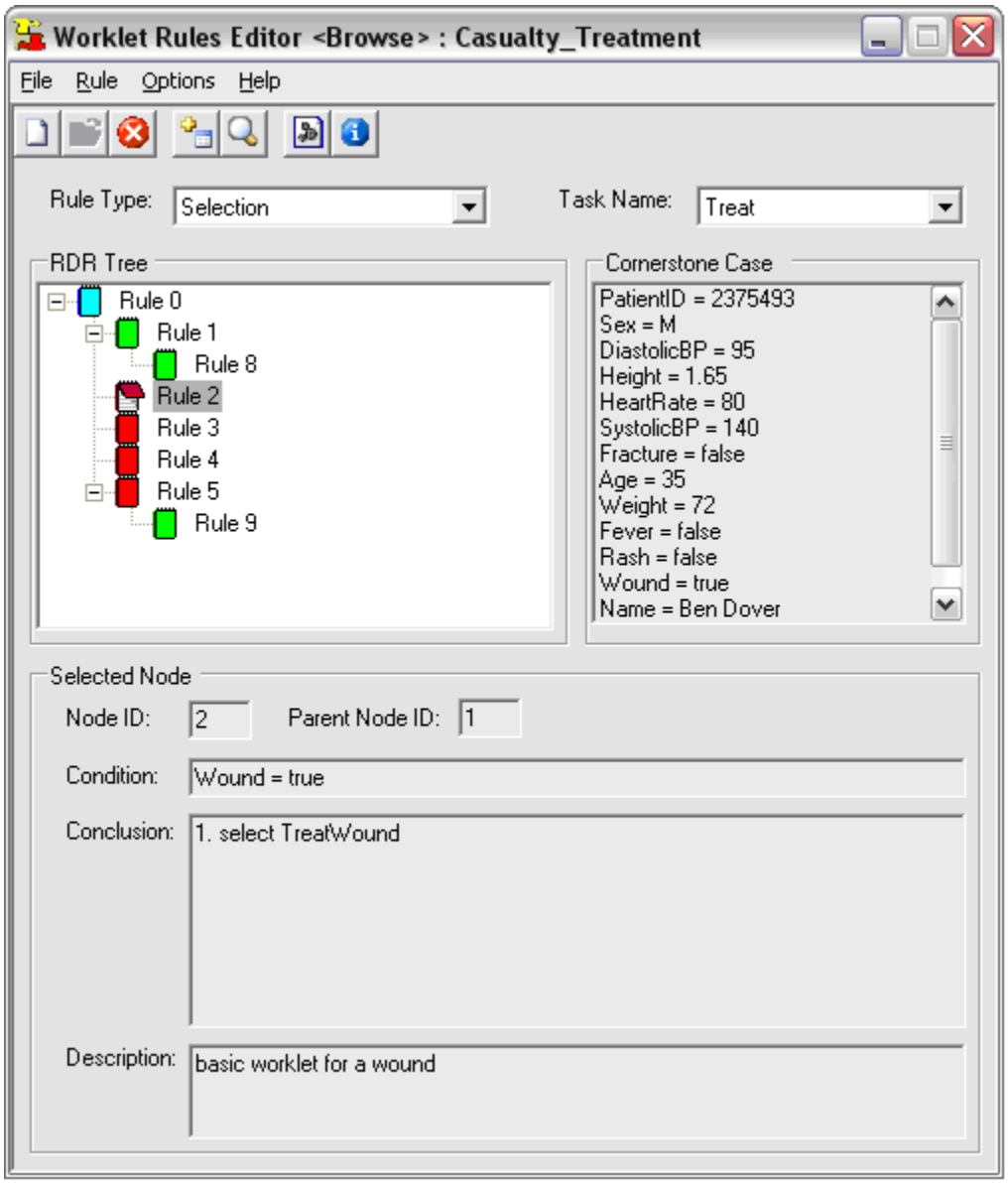


Figure 8.5: The Worklet Rules Editor

is dynamically assigned to perform a particular task at runtime, while sub-nets are statically assigned at design time. Also, worklets can be added to the repertoire at any time during the life of a specification, even while instances are running. So, rather than being forced to define all possible "branches" in a specification when it is first defined, the Worklet Service allows you to define a much simpler specification that will evolve dynamically as more worklets are added to the repertoire for a particular task as different contexts arise.

The first thing you need to do to make use of the service is to create a number of YAWL specifications - one which will act as the top-level (or manager or parent) specification, and one or more worklets which will be dynamically substituted for particular top-level tasks at runtime.

The YAWL Editor is used to create both top-level and worklet specifications. A knowledge of creating and editing YAWL specifications, and the definition of data variables and parameters for tasks and specifications, is assumed. For more information on how to use the YAWL Editor, see Chapter 4.

Before opening the YAWL Editor, make sure that the Worklet Service is correctly installed and that Tomcat is running (see Section 8.2 of this chapter and/or Chapter 2 for more information).

First, a top-level specification needs to be defined.

8.3.1 Top-level or Parent Specifications

To define a top-level specification, open the YAWL Editor, and create a process specification in the usual manner. Choose one or more tasks in the specification that you want to have replaced with a worklet at runtime. Each of those tasks needs to be associated via the YAWL Editor with the Worklet Service.

For example, Figure 8.6 shows a simple specification for a *Casualty Treatment* process. In this process, we want the *Treat* task to be substituted at runtime with the appropriate worklet based on the patient data collected in the *Admit* and *Triage* tasks. That is, depending on each patient's actual physical data and reported symptoms, we would like to run the worklet that best handles the patient's condition.

Worklets may be associated with an atomic task, or a multiple-instance atomic task. Any number of worklets can be associated with (i.e. comprise the repertoire of) an individual task, and any number of tasks in a particular specification can be associated with the Worklet Service.

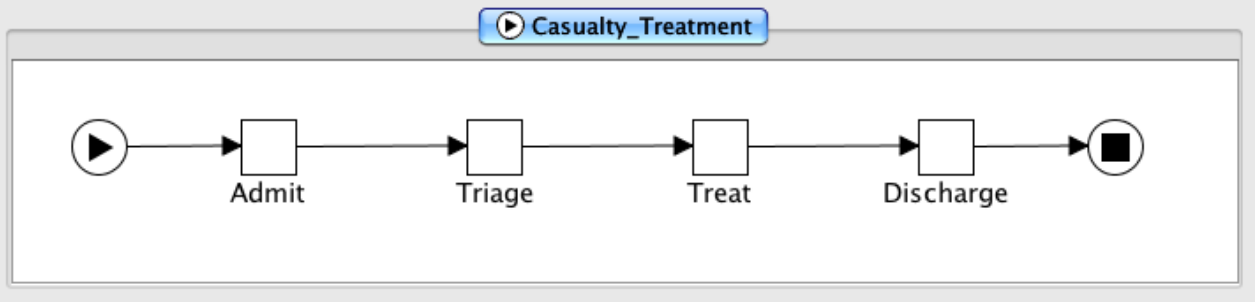


Figure 8.6: Example Top-level Specification

Here, we want to associate the Treat task with the Worklet Service. To do so, right click on the task, then select *Task Decomposition Detail* from the popup menu. The *Update Task Decomposition* dialog is shown (Figure 8.7). This dialog shows the variables defined for the task - each one of these maps to a net-level variable, so that in this example all of the data collected from a patient in the first two tasks are made available to this task. The result is that all of the relevant current case data for this process instance can be used by the Worklet Service to enable a contextual decision to be made. Note that it is not necessary to map all available case data to a worklet enabled task, only that data required by the Service to make an appropriate decision. How this data is used will be discussed later in this manual.

The list of task variables in Figure 8.7 also show that most variables are defined as 'Input Only' - this is because those values will not be changed by any of the worklets that may be executed for this task; they will only be used in the selection process. The last three variables are defined as 'Input & Output', so that the worklet can "return", or map back to these variables, data values that are captured during the worklets execution.

The dialog has a section at the bottom called *YAWL Registered Service Detail*. It is here that the task is associated with the Worklet Service by choosing the Worklet Service from the list of available services. Note that list of services will only be seen if the Engine is currently running and it has services installed.

Select the Worklet Service from the list. That's all that is required to make the top-level specification worklet-enabled. Next, we need to create one or more worklet specifications to execute as substitutes for the worklet-enabled task.

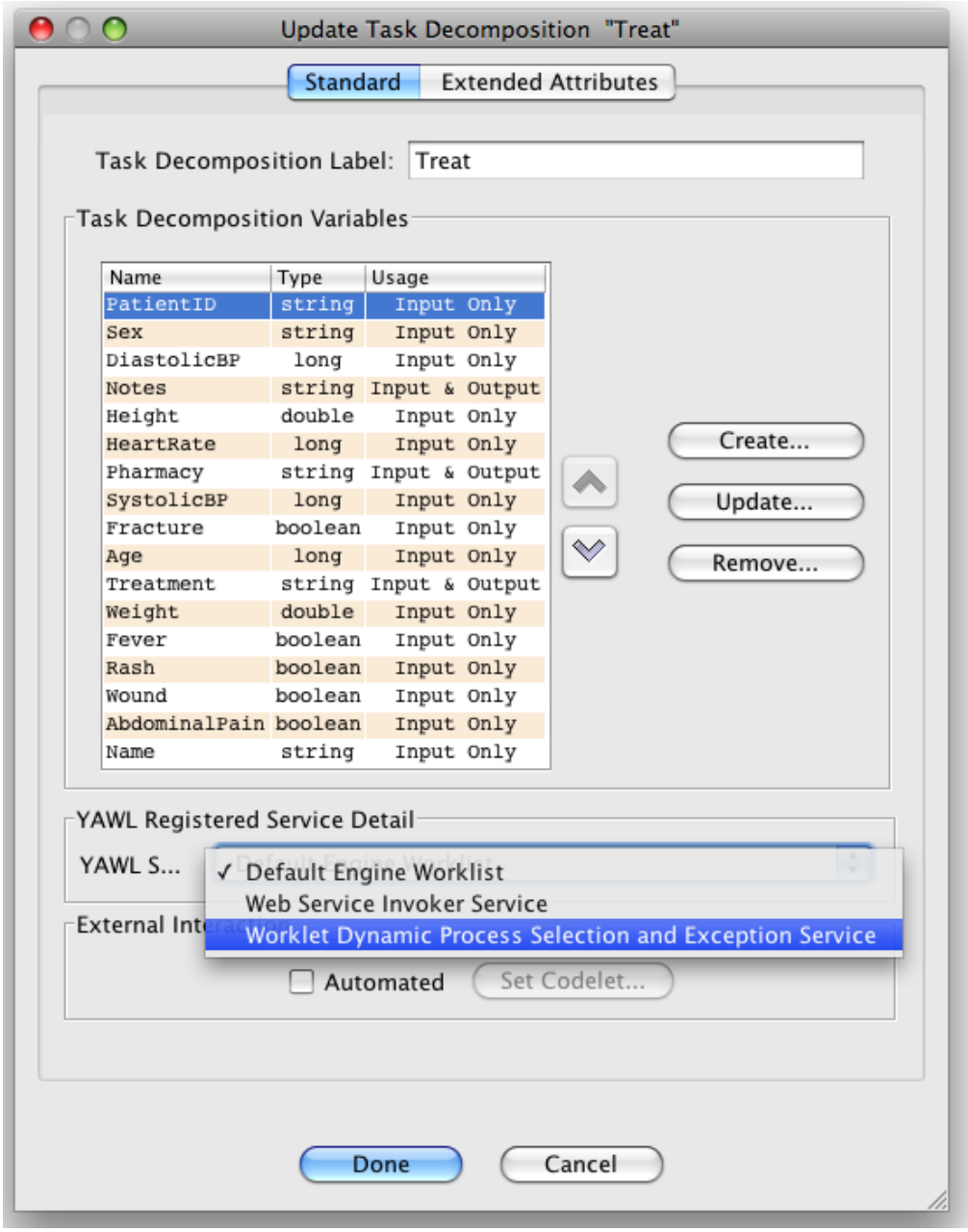


Figure 8.7: Associating a task with the Worklet Service

8.3.2 Worklet Specifications

When the *Casualty Treatment* top-level specification is executed, the YAWL Engine will notify the Worklet Service when the worklet-enabled *Treat* task becomes enabled. The Worklet Service will then examine the data in the task and use it to determine which worklet to execute as a substitute for the task. Any or all of the data in the task may also be mapped to the selected worklet case as input data. Once the worklet instance has completed, any or all of the available output data of the worklet case may be mapped back to the Treat task to become its output data, and the top-level process will continue.

A worklet specification is a standard YAWL process specification, and as such is created in the YAWL Editor in the usual manner. Each of the data variables that are required to be passed from the parent task to the

worklet specification need to be defined as net-level variables in the worklet specification.

Figure 8.8 shows a simple example worklet to be substituted for the Treat top-level task when a patient complains of a fever.

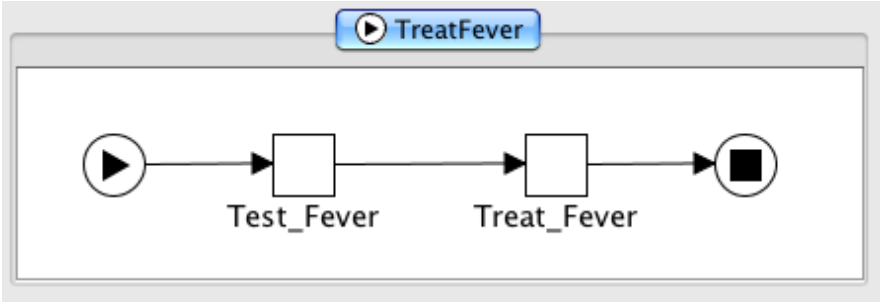


Figure 8.8: The *TreatFever* Worklet

In itself, there is nothing special about the *TreatFever* specification. Even though it will be considered by the Worklet Service as a member of the worklet repertoire and may thus be considered a "worklet", it is a standard YAWL specification and as such may be executed directly by the YAWL engine without any reference to the Worklet Service.

As mentioned previously, those data values that are required to be mapped from the parent task to the worklet need to be defined as net-level variables in the worklet specification. Figure 8.9 shows the net-level variables for the *TreatFever* task.

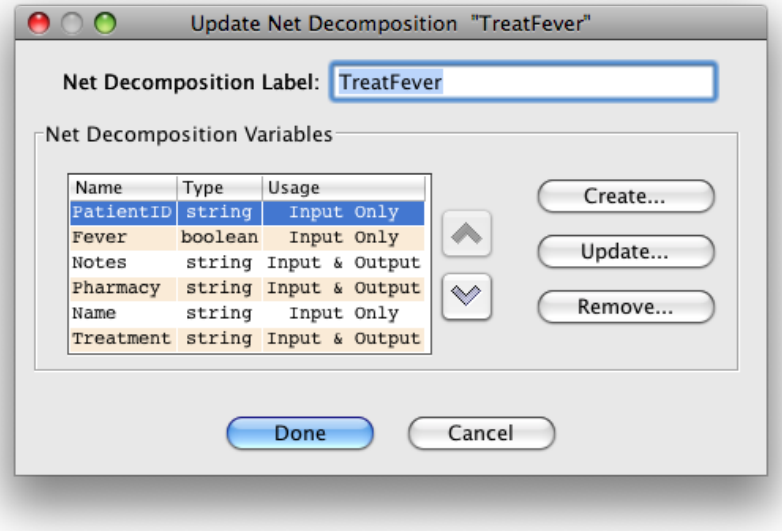


Figure 8.9: Net-level Variables for the *TreatFever* Specification

Note the following:

- Only a sub-set of the variables defined in the parent *Treat* task (see Figure 8.7) are defined here. It is only necessary to map from the parent task those variables that contain values to be displayed to the user, and/or those variables that the user will supply values for to be passed back to the parent task when the worklet completes.
- The definition of variables is not restricted to those defined in the parent task. Any additional variables required for the operation of the worklet may also be defined here.

- Only those variables that have been defined with an identical name and data type to variables in the parent task and with a *Usage* of 'Input Only' or 'Input & Output' will have data passed into them from the parent task when the worklet is launched.
- Only those variables that have been defined with an identical name and data type to variables in the parent task and with a *Usage* of 'Output Only' or 'Input & Output' will pass their data values back to the parent task when the worklet completes.

In Figure 8.9, it can be seen that the values for the *PatientID*, *Name* and *Fever* variables will be used by the *TreatFever* worklet as display-only values; the *Notes*, *Pharmacy* and *Treatment* variables will receive values during the execution of the worklet and will map those values back to the top-level *Treat* task when the worklet completes.

The association of tasks with the Worklet Service is not restricted to top-level specifications. Worklet specifications also may contain tasks that are associated with the Worklet Service and so may have worklets substituted for them, so that a hierarchy of executing worklets may sometimes exist. It is also possible to recursively define worklet substitutions - that is, a worklet may contain a task that, while certain conditions hold true, is substituted by another instance of the same worklet specification that contains the task.

Any number of worklets can be created for a particular task. For the *Casualty Treatment* example, there are (initially) five worklets in the repertoire for the *Treat* task, one for each of the five primary conditions that a patient may present with in the *Triage* task: Fever, Rash, Fracture, Wound and Abdominal Pain. Which worklet is chosen for the *Treat* task depends on which of the five is given a value of True in the *Triage* task.

How the Worklet Service uses case data to determine the appropriate worklet to execute is described in Section 8.5.2.

8.4 Using the Worklet Exception Service

In the previous Section, we saw how the Worklet Service adds dynamic flexibility to a usually static YAWL specification by substituting tasks with contextually chosen worklets at runtime. The Worklet Exception Service leverages off the worklet framework to also provide support for the myriad exceptions that may occur during the execution of any process instance.

Every process instance, no matter how rigidly structured, will experience some kind of exception during its execution. While the word 'exception' conjures up ideas of errors or problems occurring within the executing process instance, the meaning in terms of workflow processes is much broader: exceptions are merely events or occurrences that, for one reason or another, were not defined in the process model. It may be that these events are known to occur in a small number of cases, but not enough to warrant their inclusion in the process model; or they may be things that were never expected to occur (or may be never even imagined could occur). In any case, when they do happen, if they are not part of the process model, they must either be handled "off-line" before the process continues (and the way they are handled is rarely recorded) or in some instances the entire process must be aborted.

Alternately, an attempt might be made to include every possible twist and turn into the process model so that when such events occur, there is a branch in the process to take care of it. This approach may lead to very complex models where much of the original business logic is obscured, and doesn't avoid the same problems when the next unexpected exception occurs.

The Exception Service addresses these problems by allowing you to define exception handling processes (that may include worklets as compensation handlers) for parent workflow instances when certain events occur. Rules are defined in much the same way as for the Selection Service, but with added features that enable you to pause, resume, cancel or restart the task, case, or all cases of a specification, that triggered the exception.

Because the service allows you to define exception handlers for all exception events, and even to add new handlers at runtime, all exception events are able to be captured "on-system", so that the handlers are available to all future occurrences of a particular event for the same context. And, since the handlers are worklets, the original parent process model only needs to contain the actual business logic for the process,

while the repertoire of handlers grows as new exceptions arise or different ways of handling exceptions are formulated.

IMPORTANT: While the Selection Service is linked explicitly to tasks as defined in the YAWL Editor, and thus available whenever a worklet-enabled task is executed, the Exception Service is either enabled or disabled (on or off); when it is enabled, it manages exception handling for **all** process instances executed by the engine - explicitly linking a task or process to the service is not required. Also, the Selection and Exception Services can be used in combination within particular case instances to achieve dynamic flexibility and exception handling simultaneously.

8.4.1 Exception Types

This section introduces the ten different types of exception that have been identified, eight of which are supported by this version of the Worklet Service. Some are related, while others are more distinct. Later sections will show examples of each of these.

When the Exception Service is enabled, it is notified whenever any of these exception types occur for every process instance executed by the YAWL Engine (by various means). The Exception Service maintains a set of rules (described in detail in Section 8.5.2) that are used to determine which exception handling process, if any, to invoke. If there are no rules defined for a certain exception type for a specification, the exception event is simply ignored by the service. Thus you only need to define rules for those exception events that you actually want to handle for a particular specification.

Constraint Types

Constraints are rules which are applied to a workitem or case immediately before or after execution of that workitem or case begins. Thus, there are four types of constraint exception:

- **CasePreConstraint** - case-level pre-constraint rules are checked when each case (i.e. instance) begins execution;
- **ItemPreConstraint** - item-level pre-constraint rules are checked when each workitem in a case becomes enabled (i.e. ready to be checked out);
- **ItemPostConstraint** - item-level post-constraint rules are checked when each workitem moves to a completed status; and
- **CasePostConstraint** - case-level post constraint rules are checked when a case completes.

The Exception Service receives notification from the YAWL Engine when each of these events occur, then checks the rule set for the case to determine, firstly, if there are any rules of that type defined for the case, and if so, if any of the rules evaluate to true using the contextual data of the case or workitem. If the rule set finds a matching rule for the exception type and data, an exception process is invoked.

Note that for each of the constraint events, an exception process is invoked for a rule when that rules condition evaluates to **true**. So, for example, if the condition of an *ItemPreConstraint* rule for a *Triage* task was "PrivateInsurance=false", and that value of that attribute in the workitem was also false, then the exception process for that rule would be invoked.

Externally Triggered Types

Externally triggered exceptions occur, not through the case's data values, but because something has happened outside of the process execution that has an affect on the continuing execution of the process. Thus, these events are triggered by a user; depending on the actual event, a particular handler will be invoked. There are two types of external exceptions, **CaseExternalTrigger** (for case-level events) and **ItemExternalTrigger** (for item-level events). See later in this section for examples of each and how they are invoked.

TimeOut

A timeout event occurs when a workitem has an associated timer (or is linked to the deprecated Time Service) and the deadline set for that workitem is reached. In this case, the Engine notifies the Worklet Service of the timeout event, and passes to the service a reference to itself and each of the other workitems that were running in parallel with the timed-out item. Therefore, timeout rules may be defined for each of the workitems affected by the timeout (including the actual time-expired workitem itself).

ResourceUnavailable

This event occurs when an attempt has been made to allocate a workitem to a resource and the Resource Service reports that the resource is unavailable to accept the allocation.

ItemAbort

An ItemAbort event occurs when a workitem being handled by an external program (as opposed to a human user) reports that the program has aborted before completion. This event is not supported by this version of Exception Service.

ConstraintViolation

This event occurs when a data constraint has been violated for a workitem during execution (as opposed to pre or post execution). This event is not currently supported by the Exception Service.

8.4.2 Exception Handling Primitives

For any exception event that occurs, a handling process may be invoked. Each handling process, called an **exlet**, contains a number of steps, or *primitives*, in sequence, and is defined graphically using the Worklet Rules Editor (see Section 8.5.2). Each of the handling primitives is introduced below.

Suspend WorkItem - suspends (or pauses) execution of a workitem, until it is continued, restarted, cancelled, failed or completed, or its parent case is cancelled or completed.

Suspend Case - suspends all "live" workitems in the current case instance (a live workitem has a status of fired, enabled or executing), effectively suspending execution of the case.

Suspend All Cases - suspends all "live" workitems in all of the currently executing instances of the specification in which the workitem is defined, effectively suspending all running cases of the specification.

Continue Workitem - un-suspends (or continues) execution of the previously suspended workitem.

Continue Case - un-suspends execution of all previously suspended workitems for the case, effectively continuing case execution.

Continue All Cases - un-suspends execution of all previously suspended workitems for all cases of the specification in which the workitem is defined or of which the case is an instance, effectively continuing all running cases of the specification.

Remove Workitem - removes (or cancels) the workitem; execution ends, and the workitem is marked with a status of cancelled. No further execution occurs on the process path that contains the workitem.

Remove Case - removes (cancels) the case. Case execution ends.

Remove All Cases - removes (cancels) all case instances for the specification in which the workitem is defined, or of which the case is an instance.

Restart Workitem - rewinds workitem execution back to start. Resets the workitems data values to those it had when it began execution.

Force Complete WorkItem - completes a "live" workitem. Execution of the workitem ends, and the workitem is marked with a status of ForcedComplete, which is regarded as a successful completion, rather than a cancellation or failure. Execution proceeds to the next workitem on the process path.

Force Fail Workitem - fails a "live" workitem. Execution of the workitem ends, and the workitem is marked with a status of Failed, which is regarded as an unsuccessful completion, but not a cancellation - execution proceeds to the next workitem on the process path.

Compensate - run a compensatory process (i.e. a worklet). Depending on previous primitives, the worklet may execute simultaneously to the parent case, or execute while the parent is suspended (or even removed).

The primitives "Suspend All Cases", "Continue All Cases" and "Remove All Cases" may be edited so that their action is restricted to ancestor cases only. Ancestor cases are those in a hierarchy of worklets back to the parent case (that is, where a case invokes a worklet which invokes another worklet and so on).

An example of a definition of an exception handing process in the Rules Editor is below:

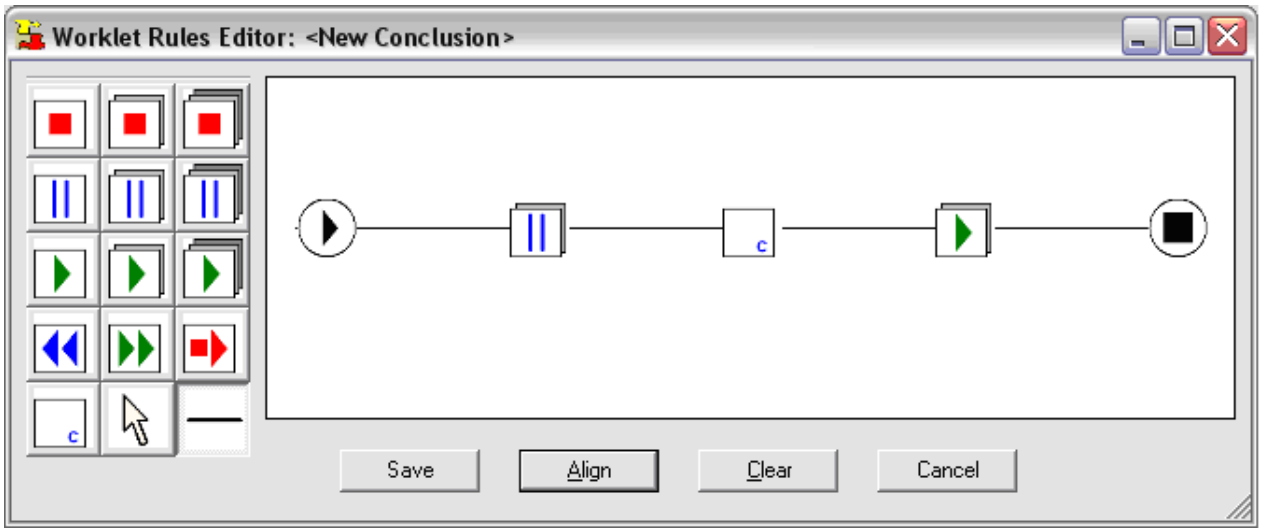


Figure 8.10: Example Handler Process in the Rules Editor

When invoked, this handler will suspend the current case, then run a compensating worklet, then continue execution of the case.

In the same manner as the Selection Service, the Exception Service also supports data mapping from a case to a compensatory worklet and back again. For example, if a certain variable has a value that prevents a case instance from continuing, a worklet can be run as a compensation, during which a new value can be assigned to the variable and that new value mapped back to the parent case, so that it may continue execution.

The full capabilities of the Exception Service are better described in the walkthroughs in Section 8.6. But

before we consider the walkthroughs, we must first look at exactly how the rule sets are formed and how they operate, and how to use the Worklet Rules Editor to manage rule sets for specifications. These topics are discussed in the next section.

8.5 Worklet Rule Sets and the Rules Editor

This section describes the structure and operation of worklet rule sets. A tool has been designed to manage the creation and modification of rule sets for specifications, called the *Worklet Rules Editor*. The structure and operation of rule sets is best described by using the Rules Editor to display and manipulate them. So a description of how to use the Rules Editor is interspersed in this section with the description of the rule sets themselves.

Again, the Worklet Selection and Exception Services work in very similar ways, but with some necessary differences. In this section, the discussion of rule sets applies to both services, except where indicated.

8.5.1 Worklet Rule Sets

Any YAWL specification may have an associated rule set. The rule set for each specification is stored as XML data in a disk file that has the same name as the specification, but with an ".xrs" extension (XML Rule Set). All rule set files are stored in the *rules* folder of the worklet repository. For example, the file *Casualty_Treatment.xrs* contains the worklet rule set for the *Casualty_Treatment.yawl* YAWL process specification. Figure 8.11 shows an excerpt from that file.

A rule set for a specification consists of a collection of *rule trees*. Each rule tree represents a set of modified *Ripple-Down Rules (RDR)*, which maintains a rule node hierarchy in a binary-tree structure. When a rule tree is queried, it is traversed from the root node of the tree along the branches, each node having its condition evaluated along the way. If a node's condition evaluates to *True*, and it has a true child, then that child nodes condition is also evaluated. If a nodes condition evaluates to *False*, and there is a false child, then that child nodes condition is evaluated. When a terminal node is reached (i.e. a node without any child nodes) if its condition evaluates to *True*, then that conclusion is returned as the result of the tree traversal; if it evaluates to *False*, then the last node in the traversal that evaluated to *True* is returned as the result. The root node (Rule 0) of the tree is always a default node with a default True condition and conclusion, and so can only have a true branch.

Effectively, each rule node on the true branch of its parent node is an exception rule to the more general one of its parent (that is, a *refinement* of the parent rule), while each rule node on the false branch of its parent node is an "else" rule to its parent (or an alternate to the parent rule). For example, see the selection rule tree for the *Casualty Treatment* specification (Figure 8.12). The condition part is the rule that is evaluated, and the conclusion is the name of the worklet selected by that rule if the condition evaluates to true. For example, if the condition "fever = true" evaluates to true, then the *TreatFever* worklet is selected (via node 1); if it is false, then the next false node is tested (node 2). If node 2 is also false, then node 3 is tested. If node 3 evaluates to true, then the *TreatAbPain* worklet is selected, *except if* the condition in its next true node (node 7) also evaluates to true, in which case the *TreatLabour* worklet is selected.

One worklet rule set file is associated with each specification, and may contain up to eleven sets of rule trees (or *tree sets*), one for selection rules and one for each of the ten exception types. Three of the eleven relate to case-level exceptions (i.e. *CasePreConstraint*, *CasePostConstraint* and *CaseExternalTrigger*) and so each of these will have only one rule tree in the tree set. The other eight tree sets relate to the workitem-level (seven exception types plus selection), and so may have one rule tree for each workitem in the specification - that is, the tree sets for these eight rule types may consist of a number of rule trees.

It is not necessary to define rules for all eleven types for each specification. You only need to define rules for those types that you want to handle - any exception types that arent defined in the rule set file are simply ignored. So, for example, if you are only interested in capturing pre and post constraints at the workitem level, then only the *ItemPreConstraint* and *ItemPostConstraint* tree sets need to be defined (i.e. rules defined within those tree sets). In this example, any *Timeout* exception events that occur during the execution of

```
      </ruleNode>
    </pre>
  </case>
</constraints>
<selection>
  <task name="Treat">
    <ruleNode>
      <id>0</id>
      <parent>-1</parent>
      <trueChild>1</trueChild>
      <falseChild>-1</falseChild>
      <condition>True</condition>
      <conclusion>null</conclusion>
      <cornerstone> </cornerstone>
      <description>root level default node</description>
    </ruleNode>
    <ruleNode>
      <id>1</id>
      <parent>0</parent>
      <trueChild>8</trueChild>
      <falseChild>2</falseChild>
      <condition>Fever = true</condition>
      <conclusion>
        <_1>
          <action>select</action>
          <target>TreatFever</target>
        </_1>
      </conclusion>
      <cornerstone>
```

Figure 8.11: Excerpt of Rule Set file Casualty_Treatment.xrs

the specification would be ignored by the Exception Service. Of course, rules for a *Timeout* event could be added later if required (as could any of the other types not yet defined in the rule set).

Referring back to Figure 8.11, notice that the file specifies a *Selection* rule tree for the Treat task. The second *ruleNode* contains a condition "Fever = True" and a conclusion of "TreatFever". Thus, when the condition "Fever = True" evaluates to true, the worklet *TreatFever* is chosen as a substitute for the *Treat* task. Notice also that each rule node (except the first) has a parent, and may have two child nodes, a *true* child and a *false* child.

To summarise the hierarchy of a rule set (from the bottom up):

- **Rule Node:** contains the details (condition, conclusion, id, parent and so on) of one discrete ripple-down rule.
- **Rule Tree:** consists of a number of rule nodes in a binary tree structure.
- **Tree Set:** a set of one or more rule trees. Each tree set is specific to a particular rule type (timeout, selection, etc.). The tree set of a case-level exception rule type will contain exactly one tree. The tree set of an item-level rule type will contain one rule tree for each task of the specification that has rules defined for it (not all tasks in the specification need to have a rule tree defined).
- **Rule Set:** a set of one or more tree sets representing the entire set of rules defined for a specification.

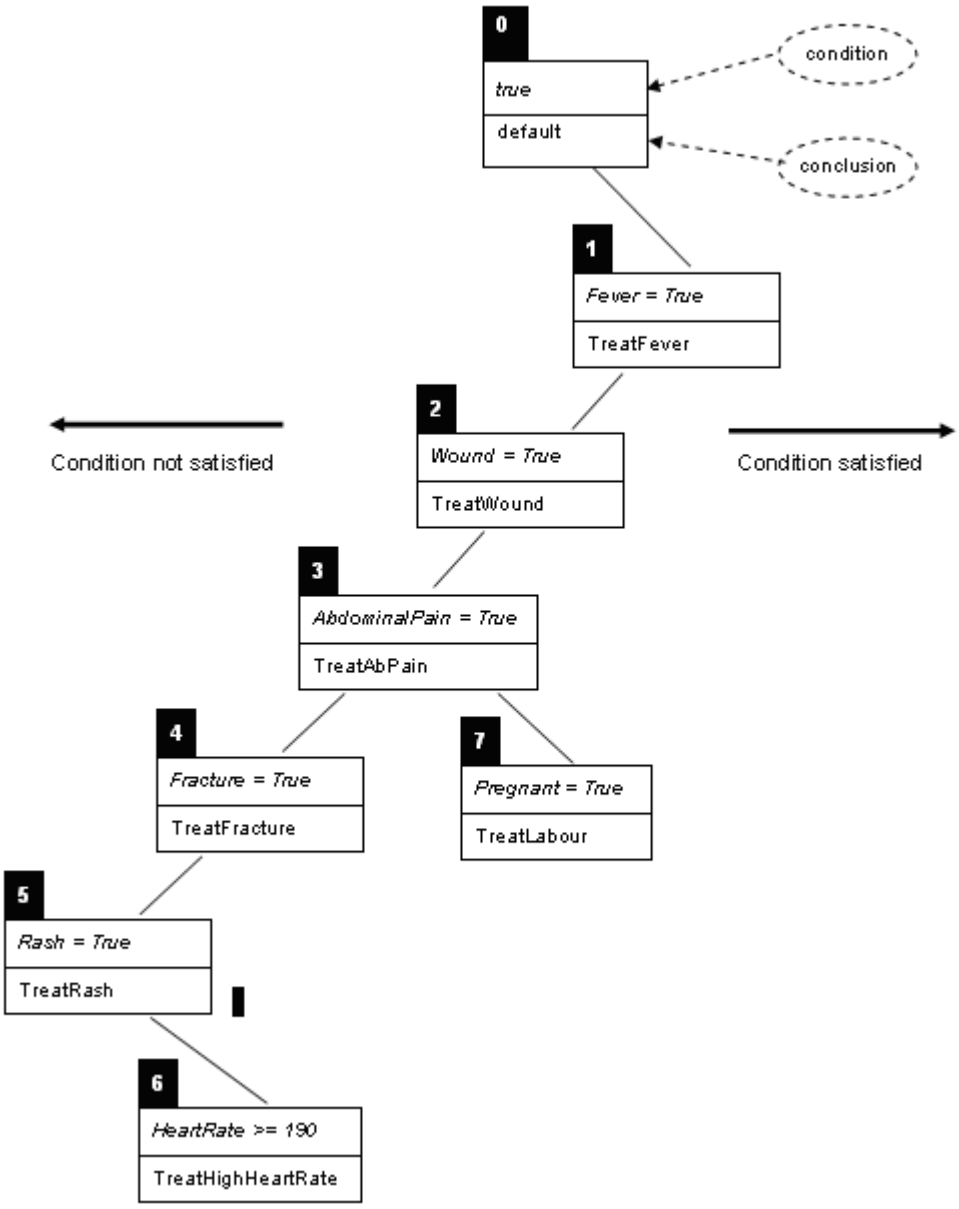


Figure 8.12: Example Rule Tree (Casualty Treatment spec)

Each rule set is specific to a particular specification. A rule set will contain one or more tree sets - one for each rule type for which rules have been defined.

Of course, to maintain a rule set of any complexity by directly editing the XML in a rule set file would be daunting, to say the least. To make things much easier, a *Rules Editor tool* has been developed, and can be found in the *rulesEditor* folder of the worklet repository. It can be run directly from there - no further installation is required (depending on the requirements below).

8.5.2 The Rules Editor

The Worklet Rules Editor allows for the addition of new rules to existing rule sets of specifications, and the creation of new rule sets. It is a .NET based application, so has the following requirements:

- Operating System: Windows 98SE or later.
- The Microsoft .NET framework (any version). If you dont have the framework installed, it can be downloaded free from Microsoft.

When the Rules Editor is run for the first time, the following dialog shown in Figure 8.13 is displayed.

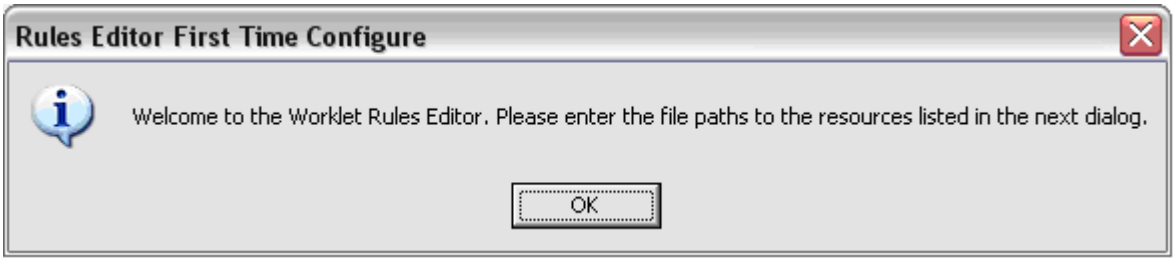

Rules Editor First Time Configure
Welcome to the Worklet Rules Editor. Please enter the file paths to the resources listed in the next dialog.
OK

Figure 8.13: Rules Editor First Time Use Message

Clicking OK shows the *Configuration* dialog (Figure 8.14), where the paths to resources the Rules Editor uses are to be specified. Some default paths are shown, but can be modified directly or by using the browse buttons where available. he following paths must be specified:

- **Worklet Service URI:** the URI to the Worklet Service. The default URI assumes it is installed locally. If it is remote to the computer running the Rules Editor, then that URI should be entered, ensuring it ends with "/workletService".
- **Worklet Repository:** the path where the worklet repository was installed. The default path shown assumes the Rules Editor was started from the *rulesEditor* folder of the repository. If it was started from another location, specify the actual path to the repository by editing the path or browsing to the correct location.
- **Specification Paths:** the path or paths to locations on the local computer where YAWL specification files may be found. The rules editor will search each of the paths provided for specifications for which rule sets may be created. Multiple paths can be provided, separated by semicolons ';'
- **YAWL Editor:** the path and filename for the YAWL Editor.

Some checks will take place to make sure the paths are valid and you will be asked to correct any that are not. Once the configuration is complete, the main screen will appear. This screen allows you to view each node of each rule tree defined for a particular specification. From this screen you can also add new rules to the current rule set, create new tree sets for an existing rule set, and create entirely new rule sets for new specifications.

8.5.3 Browsing an Existing Rule Set

To load a rule set into the Rules Editor, click on the *File* menu, then select *Open...*, or click on the *Open* toolbar button. The File Open Dialog will open with the *rules* folder of the repository selected. Select the file you wish to open, and then click OK.

Figure 8.15 shows the main screen with the rule set for the *Casualty Treatment* specification loaded. On this screen, you may browse through each node of a rule tree set and view the various parts of each node. The main features of the screen are explained below.

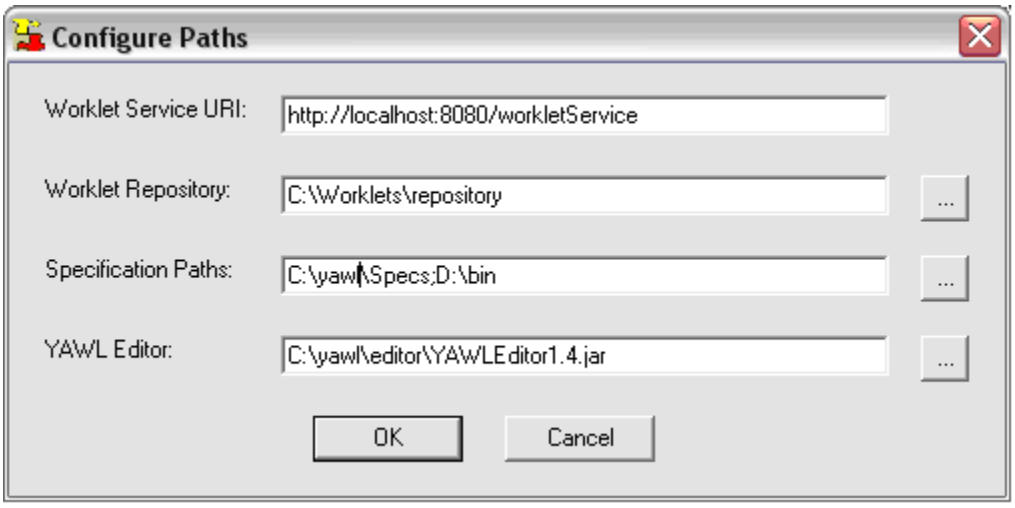


Figure 8.14: The Rules Editor Configuration Dialog

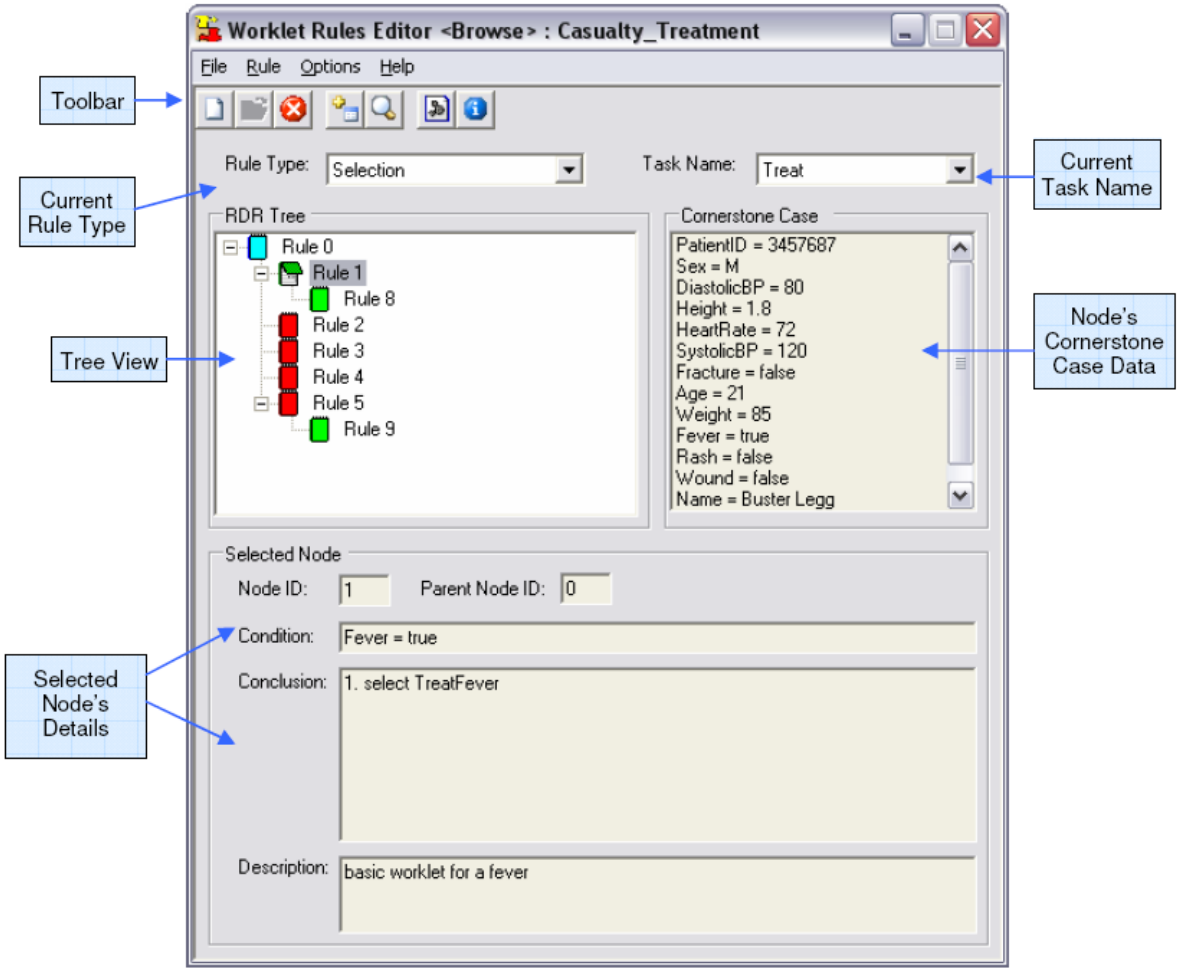


Figure 8.15: Rules Editor Main Screen

The Toolbar

The toolbar buttons replicate the functions available from the main menu see Figure 8.16.

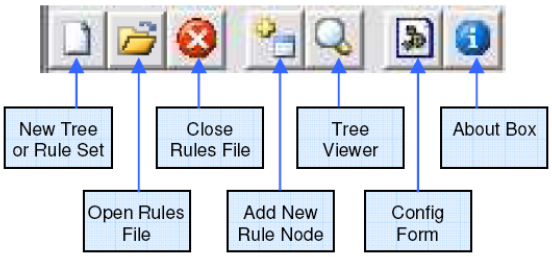


Figure 8.16: Toolbar

- **New Tree or Rule Set:** If there is no rules file currently open in the Editor, this button displays the *New Rule* form to allow the creation of an entirely new rule set file for a specification (i.e. one that does not yet have a rule set file defined). If there is a rules file currently open in the Editor, displays the *New Rule* form to allow the addition of new tree sets to the opened rule set file (for rule types that have not yet been defined for that specification). See the *Creating a New Rule Set and/or Tree Set* section below for more details.
- **Open Rules File:** Opens an existing rules file for browsing and/or editing. The title bar shows the name of the specification associated with the currently loaded rule set.
- **Close Rules File:** Closes the currently opened rules file. Only one rules file may be open at any one time.
- **Add New Rule Node:** Displays the *Add Rule* form to allow the addition of a new rule node to an existing tree to refine a worklet selection. See the section below on the *Adding a New Rule* for more details.
- **Tree Viewer:** Displays the *Tree Viewer* form, which provides the ability to view large trees in full-screen mode.
- **Config Form:** Displays the configuration form discussed above.
- **About Box:** Displays some information about the rules editor (version number, date and so on).

Other Features

- **Current Rule Type:** This drop-down list displays each rule type that has a tree set defined in the opened rules file. Selecting a rule type from the list displays in the *Tree View* an associated rules tree from the tree set. Works in conjunction with the *Task Name* drop-down list.
- **Current Task Name:** This drop-down list displays the name of each task that has a rules tree associated with it for the rule type selected in the *Rule Type* list. Selecting a task name will display the rules tree for that task in the *Tree View*. This drop-down list is disabled for case level rules types.
- *Tree View:* This area displays the currently selected rules tree in a graphical tree structure. Selecting a node in the tree will display the details of that node in the *Selected Node* and *Cornerstone Case panels*. Nodes are colour coded for easier identification:
  - Blue nodes represent the root node of the tree
  - Green nodes are **true** (**exception**) nodes (i.e. they are on a true branch from their parent node)

  - Red nodes are **false** (**else**) nodes (i.e. they are on a false branch from their parent node)

- **Selected Node:** Displays the details of the node currently selected in the *Tree View*.

- **Cornerstone Case:** displays the complete set of case data that, in effect, caused the creation of the currently selected rule (see *Adding a new rule* below for more details). In Figure 8.15, the Cornerstone Case data shows that, amongst other things, the variable *Fever* had a value of true, while the variables *Rash*, *Wound* and *Fracture* each have value of false.

8.5.4 Adding a New Rule

There are occasions when the worklet returned for a particular case, while the correct choice based on the current rule set, is an inappropriate choice for the case. For example, if a patient in a *Casualty Treatment* case presents with a rash and a heart rate of 190, while the current rule set correctly returns the *TreatRash* worklet, it may be desirable to treat the racing heart rate before the rash is attended to. In such a case, as the Worklet Service begins execution of an instance of the *TreatRash* process, it is obvious that a new rule needs to be added to the rule set so that cases that have such data (both now and in the future) will be handled correctly.

To add a new rule to a particular tree of a rule set, it is first necessary to open the rule set in the Rules Editor (as described above). Then, click *Rules* on the top menu, then *Add...*, or click the *Add Rule* toolbar button, to open the (initially blank) *Add Rule* form.

Notice that the name of the opened rule set is shown in the title bar of the form, and the rule type and task name that are currently selected on the main form have been transferred to the *Add Rule* form. Thus, to add a new rule to a rule tree, that rule tree must first be selected on the main Rules Editor form before the *Add Rule* form is opened.

Every time the Worklet Service selects a worklet to execute for a specification instance, a log file is created that contains certain descriptive data about the worklet selection process. These files are stored in the *selected* folder of the worklet repository. The data stored in these files are again in XML format, and the files are named according to the following format:

CaseID_SpecificationID_RuleType_WorkItemID.xws

For example: *12_CasualtyTreatment_Selection_Treat.xws* (xws for Xml Worklet Selection). The identifiers in each part of the filename refer to the parent specification instance, not the worklet case instance. Also, the *WorkItemID* identifier will not appear for case-level rule types.

So, to add a new rule after an inappropriate worklet choice, the particular *selected* log file for the case that was the catalyst for the rule addition must be located and loaded into the Rules Editor.

From the *Add Rule* screen, click the *Open...* button to load the selection information from the relevant *selected* log file. The File Open dialog that displays will open in the *selected* folder of the repository. Select the appropriate file for the case in question then click OK. Note that the *selected* file chosen must be for an instance of the specification that matches the specification rule set loaded on the main screen (in other words, you cant attempt to add a new rule to a rule set that has no relation to the *xws* file opened here). If the specifications dont match, an error message will display.

Figure 8.17 shows the *Add Rule* form with the *selected* file *12_CasualtyTreatment_Selection_Treat.xws* loaded. The *Cornerstone Case* panel shows the case data that existed for the creation of the original rule that resulted in the selection. The *Current Case* panel shows the case data for the current case - that is, the case that is the catalyst for the addition of the new rule.

The *New Rule Node* panel is where the details of the new rule may be added. Notice that the ids of the parent node and the new node are shown as read only - the Rules Editor takes care of where in the rule tree the new rule node is to be placed, and whether it is to be added as a true child or false child node.

IMPORTANT: Since we have the case data for the original rule, and the case data for the new rule, to define a condition for the new rule it is only necessary to determine what it is about the current case that makes it require the new rule to be added. That is, it is only where the case data items *differ* that distinguish one case from the other, and further, only a subset of that differing data is relevant to the reason why the original selection was inappropriate.

For example, there are many data items that differ between the two case data sets shown in Figure 8.17, such as *PatientID*, *Name*, *Sex*, *Blood Pressure readings*, *Height*, *Weight* and *Age*. However, the only differing data item of relevance here is *HeartRate* - that is the only data item that, in this case, makes the selection of the *TreatRash* worklet inappropriate.

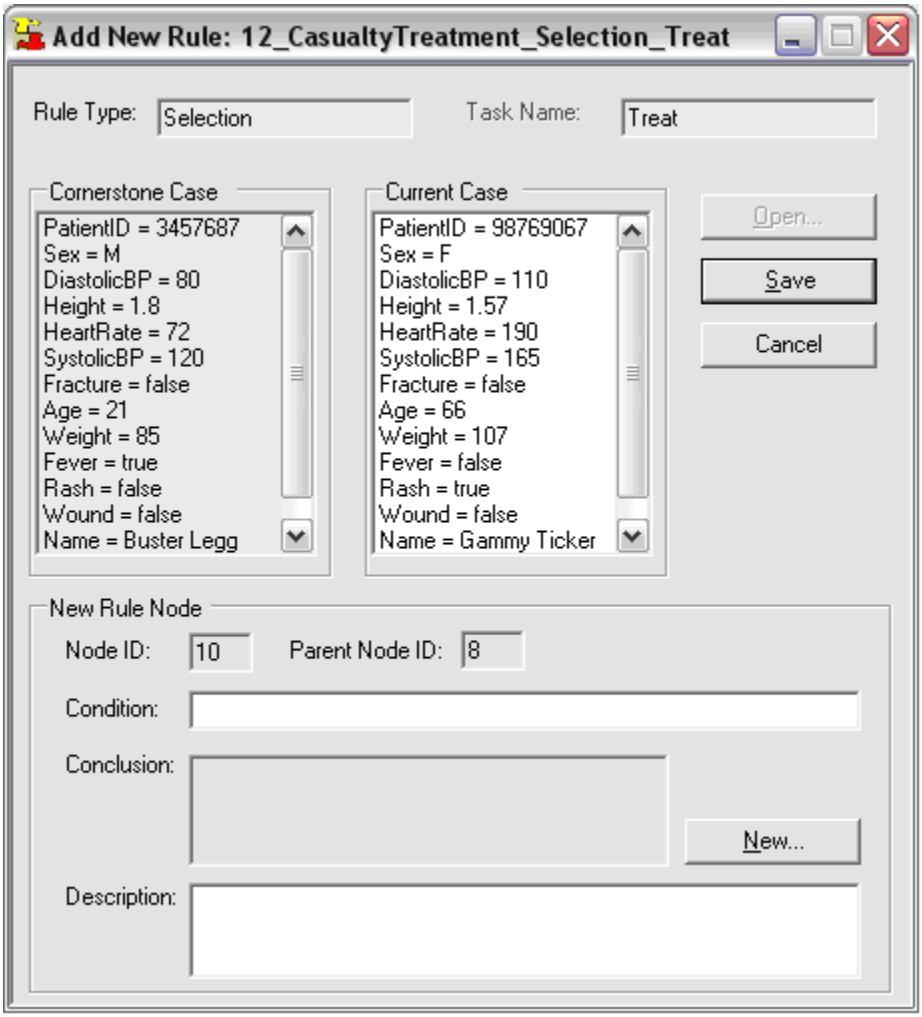


Figure 8.17: Add New Rule Form

Clicking on the line "HeartRate = 190" in the *Current Case* panel copies that line to the *Condition* input in the *New Rule Node* panel. Thus, a condition for the new rule has been easily created, based on the differing data attribute and value that has caused the original worklet selection to be invalid for this case.

Note that it is not necessary to define the rule as "Rash = True & HeartRate = 190", as might first be expected, since this new rule will be added to the true branch of the *TreatRash* node. By doing so, it will only be evaluated if the condition of its parent, "Rash = True", first evaluates to True. Therefore, any rule nodes added to the true branch of a parent become **exception** rules of the parent. In other words, this particular tree traversal can be interpreted as: "if Rash is True then return TreatRash **except** if HeartRate is also 190

then return ???" (where ??? = whatever worklet we decide to return for this rule - see more below).

Now, the new rule is fine if, in future cases, a patients heart rate will be exactly 190, but what if it is 191, or 189, or 250? Clearly, the rule needs to be amended to capture all cases where the heart rate exceeds a certain limit; say 175. While selecting data items from the *Current Case* panel is fast and easy, it is often the case that the condition needs to be further modified to correctly define the relevant rule. The *Condition* input allows direct editing of the condition.

Conditions are expressed as strings of operands and operators of any complexity, and sub-expressions may be parenthesised. The supported operators are shown in Figure 8.18.

Precedence	Operators	Type
1	* /	Arithmetic
2	+ −	
3	= > < != >= <=	Comparison
4	&	Logical AND
	|	Logical OR
	!	Logical NOT

Figure 8.18: Operators Supported

All conditions must finally evaluate to a Boolean value (i.e. true or false).

TIP: In addition to conditions expressed in the above mentioned format, conditional expressions may also take the form of XQuery expressions that evaluate to a boolean value.

To make the condition for the new rule more appropriate, the condition "HeartRate = 190" should be edited to read "HeartRate > 175".

After defining a condition for the new rule, the name of the worklet to be executed when this condition evaluates to true must be entered in the read-only *Conclusion* field of the *New Rule Node* panel (refer Figure 8.17). To select or create an appropriate worklet, click the *New...* button.

What happens next depends on whether the rule type for the tree you are adding the new rule to is of Selection type, or one of the exception types. Adding a conclusion for a Selection rule is explained below. Refer to the *Creating a New Rule Set and/or Tree Set* section below for details on adding a conclusion for the exception types.

8.5.5 Adding a Conclusion - Selection Rule Type

For a Selection rule tree, when the *New..* button is clicked, a dialog is displayed that comprises a drop-down list containing the names of all the worklets in the worklets folder of the worklet repository (refer Figure 8.19). An appropriate worklet for this rule may be chosen from the list, or, if none of the existing worklets are suitable, a new worklet specification may be created.

Clicking the *New...* button on this dialog will open the YAWL Editor so that a new worklet specification can be created. When defining the new worklet, bear in mind that to pass data from the original work item to the worklet, the names and data types of the variables to be passed must match those of the work item and be created as net-level variables in the worklet specification. Also, all new worklets must be saved to the *worklets* folder of the repository so that the Worklet Service can access it.

TIP: You may choose more than one worklet in this dialog simultaneously by holding down the Ctrl or Alt keys while clicking the mouse (in the usual Windows way). If you choose several worklets, when this rule

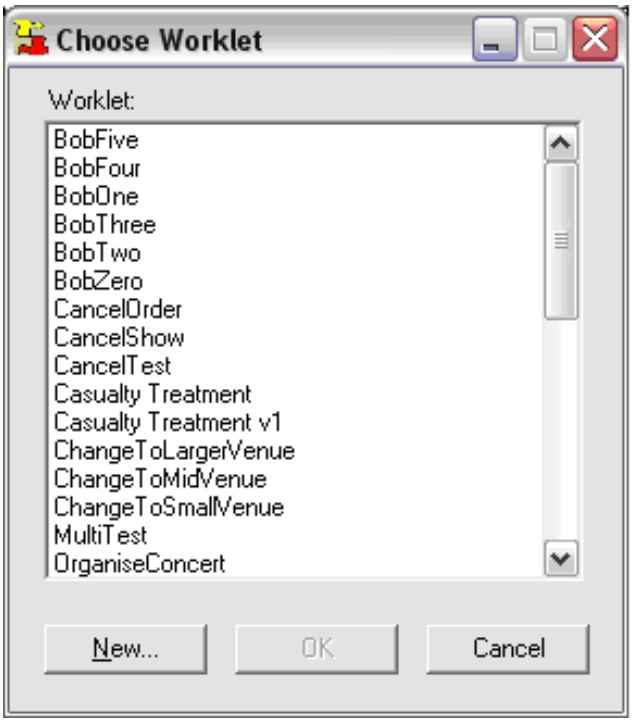


Figure 8.19: The Choose Worklet dialog

is invoked for a process at runtime **all** of the worklets chosen will be launched concurrently and the process will continue only after **all** the worklets launched have completed.

When the new worklet is saved and the YAWL Editor is closed, the name of the newly created worklet will be displayed and selected in the worklet drop-down list. Click the OK button to confirm the selection and close the dialog. Figure 8.20 shows the *New Rule Node* panel after the definition of the example new rule has been completed. A value in the *Description* field is optional, but recommended.

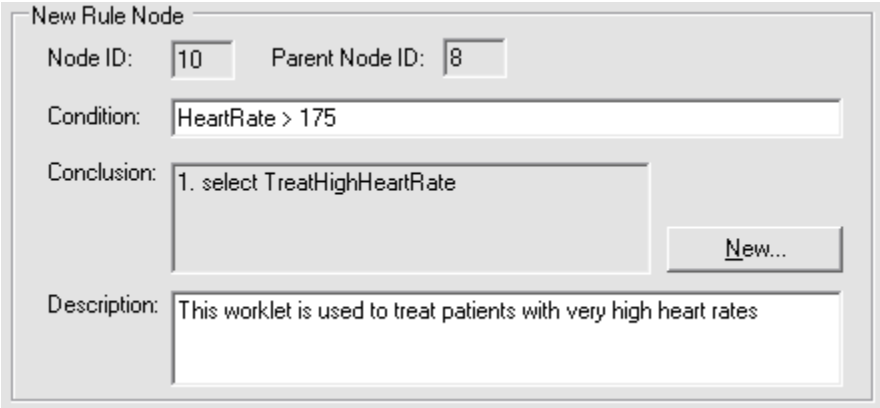


Figure 8.20: The *New Rule Node* Panel after a New Rule has been Defined

Once all the fields for the new rule are complete and valid, click the *Save* button to add the new rule to the rule tree.

8.5.6 Dynamic Replacement of an Executing Worklet

Remember that the creation of this new rule was triggered by the selection and execution of a worklet that was deemed an inappropriate choice for the current case. So, when a new rule is added, you are given the choice of replacing the executing (inappropriate) worklet instance with an instance of the worklet defined in the new rule.

After the *Save* button is clicked, a message similar to the Figure 8.21 is shown, providing the option to replace the executing worklet, using the new rule. The message also lists the specification and case ids of the original work item, and the name and case id of the running worklet instance.

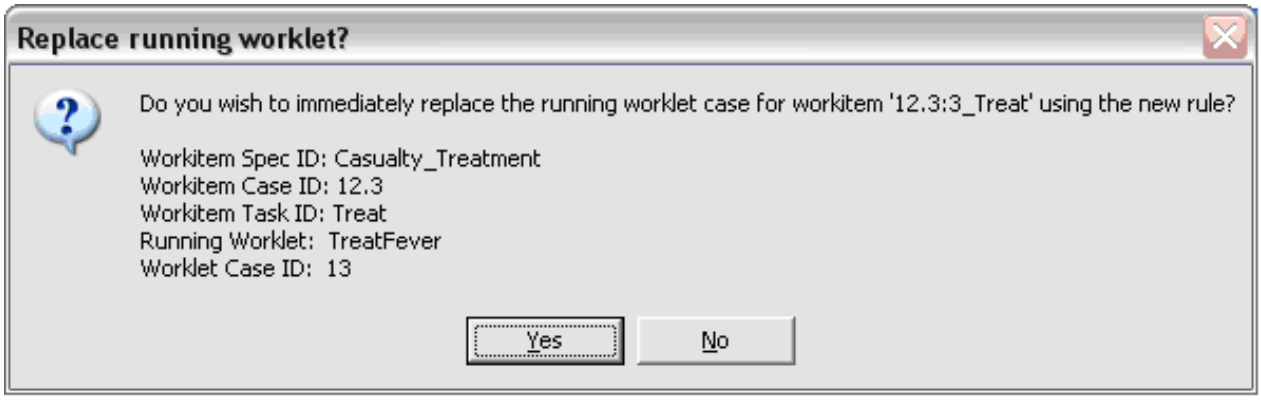

Replace running worklet?
Do you wish to immediately replace the running worklet case for workitem '12.3:3_Treat' using the new rule?
Workitem Spec ID: Casualty_Treatment
Workitem Case ID: 12.3
Workitem Task ID: Treat
Running Worklet: TreatFever
Worklet Case ID: 13
Yes
No

Figure 8.21: Message Dialog Offering to Replace the Running Worklet

If the *Yes* button is clicked, then in addition to adding the new rule to the rule set, the Rules Editor will contact the Worklet Service and request the change. For this process to succeed, the following must apply:

- Tomcat is currently running and the Worklet Service is correctly installed;
- The Service URI specified in the Rules Editor configuration dialog is valid; and
- The worklet originally chosen is currently running.

A message dialog will be shown soon after with the results of the replacement process sent from the Worklet Service back to the Rules Editor, similar to Figure 8.22.

If the *No* button is clicked, then the new rule is simply added to the rule set.

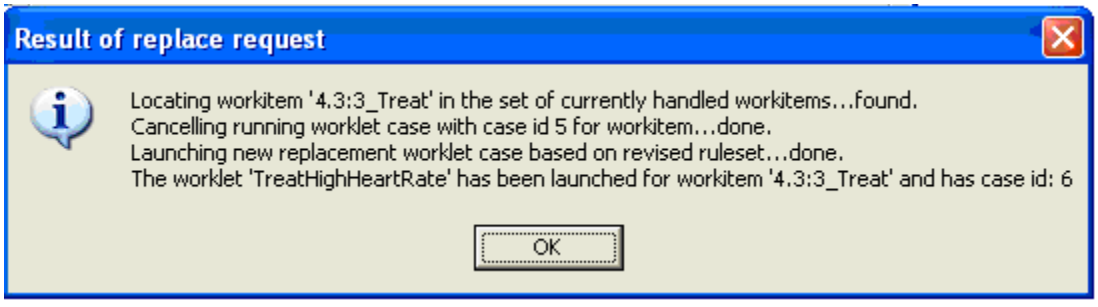

Result of replace request
Locating workitem '4.3:3_Treat' in the set of currently handled workitems...found.
Cancelling running worklet case with case id 5 for workitem...done.
Launching new replacement worklet case based on revised ruleset...done.
The worklet 'TreatHighHeartRate' has been launched for workitem '4.3:3_Treat' and has case id: 6
OK

Figure 8.22: Result of Replace Request Dialog

Figure 8.23 shows the main Rules Editor screen with the new rule added in the correct place in the tree, with the current case data becoming the *Cornerstone Case* for the new rule.

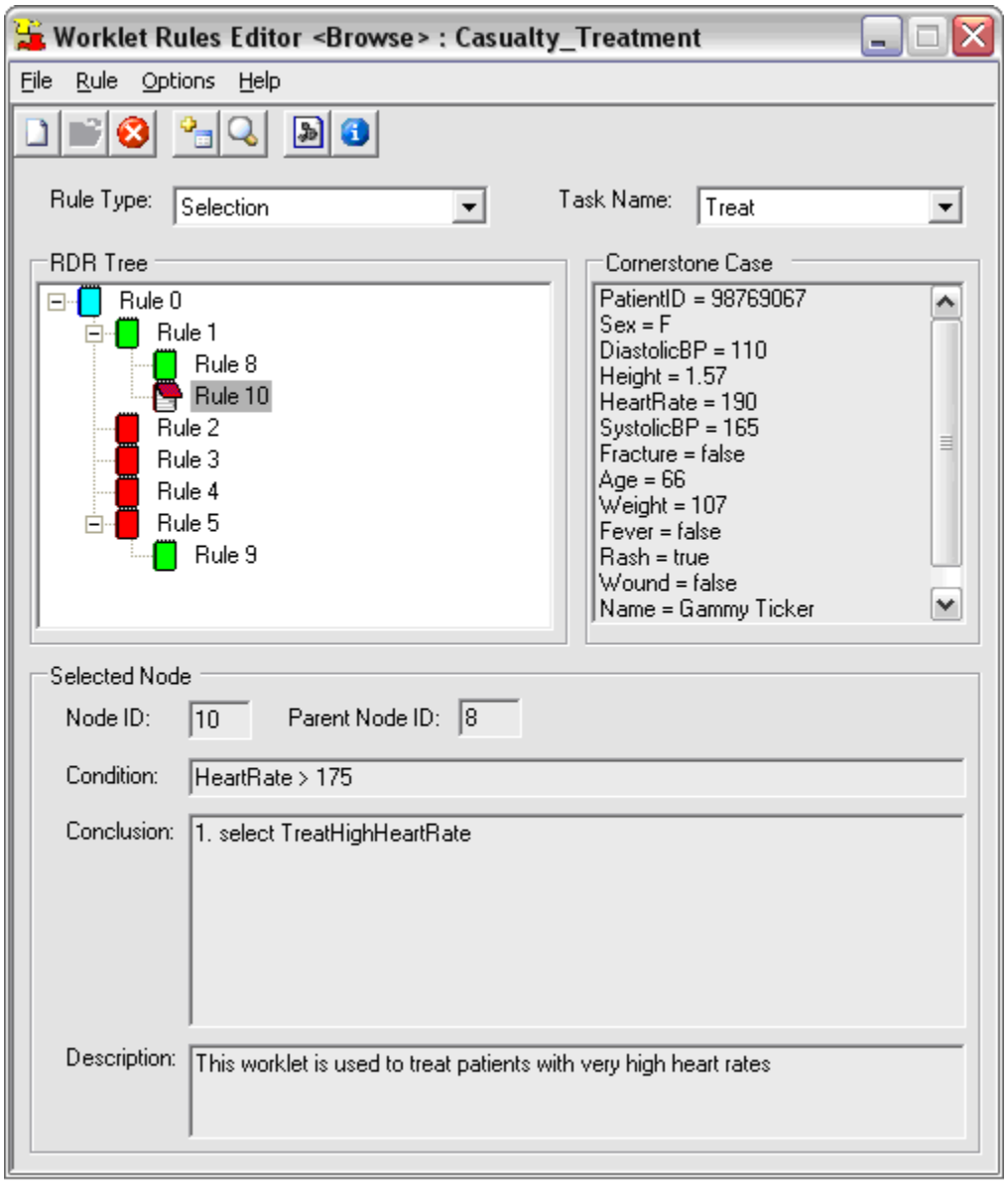


Figure 8.23: Main Screen after Addition of New Rule

8.5.7 Creating a New Rule Set and/or Tree Set

As mentioned previously, it is not necessary to create tree sets for all of the rule types, nor a rule tree for an item-level rule type encompassing every task in a specification. So, most typically, rule sets will have rules defined for a few rule types, with some tasks left undefined (remember that any events that don't have associated rules for that type of event are simply ignored).

It follows that there will be occasions where you will want to add a new tree set to a rule set for a previously undefined rule type, or add a new tree for a previously undefined task to an existing tree set. Also, when a new specification has been created, a corresponding base rule set will also need to be created (if you want to handle selections and exceptions for the new specification).

For each of these situations, the Rules Editor provides a *New Rule* form, which allows the definition of new rule trees (with any number of rule nodes) for existing tree sets (where there is a task of the specification that has not yet had a tree defined for it within the tree set); the definition of new tree sets for specifications

that have not yet had a tree set defined for a particular rule type; and entirely new rule sets for specifications that have not yet had a rule set created for them.

The use of the *New Rule* form varies slightly depending on whether it is working with a new rule set or an existing rule set. This section will describe the features of the *New Rule* form for adding a new rule set, and describe how the process differs for existing rule sets as necessary.

To create a new rule set, click the *File* menu then select *New...*, or click the New Rule toolbar button. To add a new rule set, make sure there is no rule set file currently open in the Editor. If you are creating a new rule set, a dialog will display asking for the path and file name of the specification for which the rule set is being created (Figure 8.24).

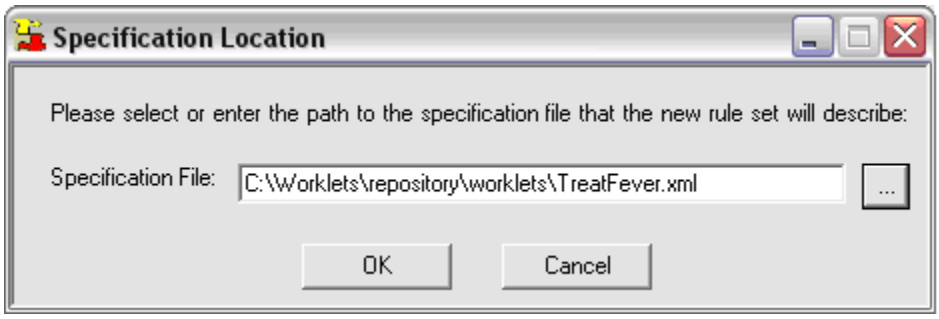


Figure 8.24: The Specification Location Dialog

Figure 8.25 shows the *Create New Rule Set* form. The form allows you create a rule set, one rule tree at a time (for the selected specification, rule type and task name). On this form:

- The *Process Identifiers* panel is where the names of the specification, rule type and task name for the new tree are defined. The *Specification Name* input is read-only - for new rule sets it is the specification chosen via the *Specification Location* dialog (Figure 8.24); for existing rule sets it is the specification for the rule set currently loaded into the Rules Editor. The *Rule Type* drop-down list contains all of the available rule types (i.e. all the rule types for which no or incomplete tree sets exist). For new rule sets, all rule types are available. The *Task Name* drop-down list contains all the available tasks for the selected rule type (i.e. tasks for which no tree exists in the tree set for this rule type). The *Task Name* list is disabled for case-level rule types.

- The *New Rule Node* panel is identical to the panel on the Add New Rule form. Here a condition and optional description can be entered, and the conclusion for the new rule created or selected from the list (depending on the rule type - see below).

- The *Cornerstone Case Data* panel allows a set of cornerstone data for the new rule to be defined. Add a variable name to the *Attribute* input, and give it a value in the *Value* input, then click the *Add* button to add it to the set of Cornerstone Case data. Usual naming rules apply to the data attributes: the attribute name must begin with an alpha character or underscore and contain no spaces or special characters.

- The *Effective Composite Rule* panel displays a properly indented text equivalent of the composite condition comprising the conditions of the selected node and all ancestor nodes back to the root node - in other words, the entire composite condition that must evaluate to true for the conclusion of the selected node to be returned.

- The *RDR Tree* panel dynamically displays graphically the new rule tree as it is being created.

New rule nodes can be added wherever there is a node on the tree that does not have a child node on both its true and false branches (except the root node which can have a true branch only). To identify possible

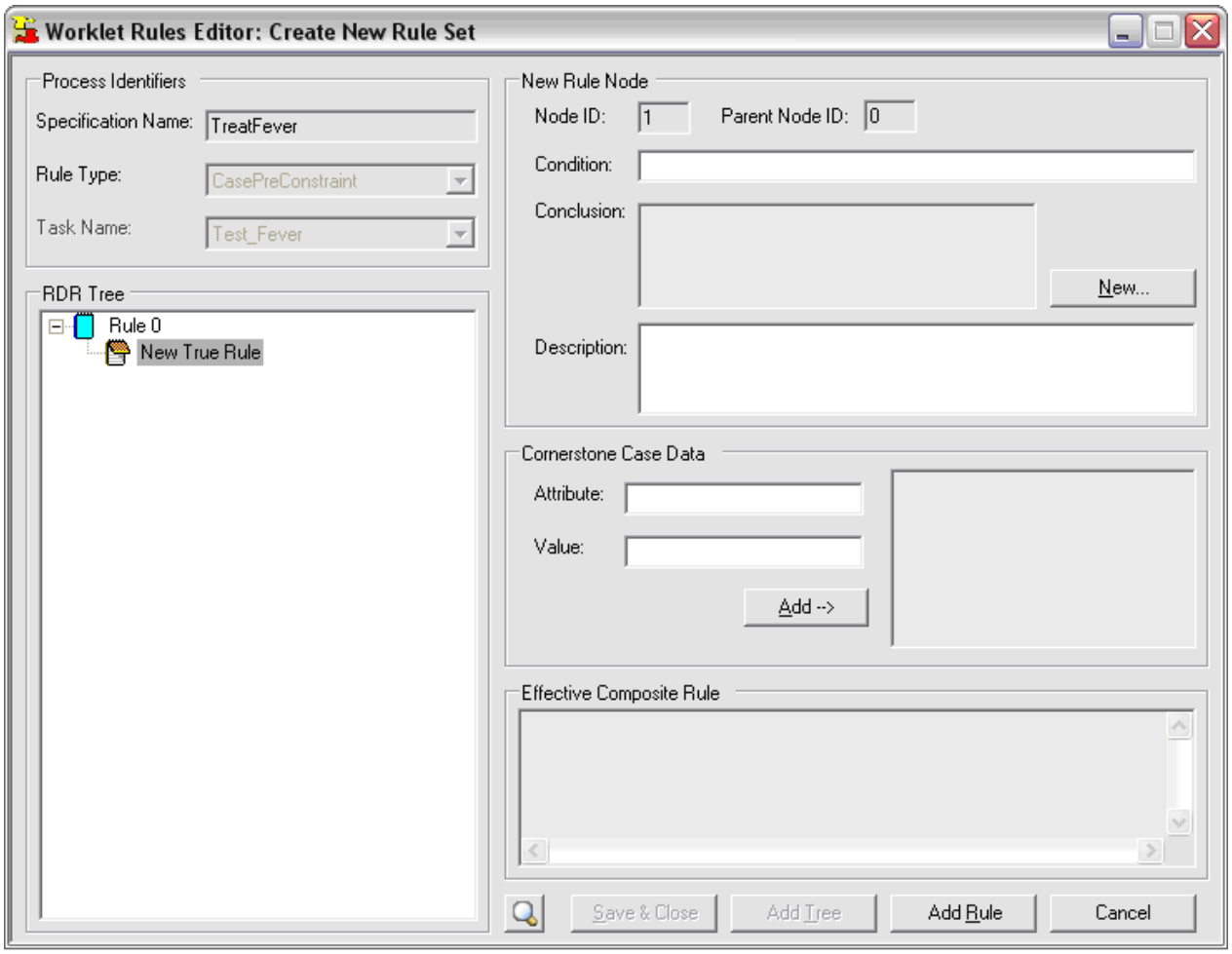


Figure 8.25: The Create New Rule Set Screen

locations to add a rule node, special 'potential nodes can be seen in the *RDR Tree* panel, called "New True Node" or "New False Node". These potential nodes are coloured yellow for easy identification.

To add a new rule, select the yellow new rule node where you would like the rule to be added. When you select a new rule node, the various inputs for the new rule become enabled. Refer to the *Adding a New Rule* section above for details of the types of operands and operators you can add as the condition of the new rule.

To add a conclusion to the new rule, click the *New...* button. If the currently selected rule type is *Selection*, a worklet can be added as a conclusion in the way described in the *Adding a New Rule* section. If it is one of the exception rule types, the *New...* button will display the graphical *Draw Conclusion* dialog, allowing you to build a sequence of tasks (or primitives) in an exception handling process (explained in detail below). When the conclusion sequence has been defined and the dialog closed, a text-based version of it will display in the *Conclusion* panel.

Once the new rule node has a valid condition and conclusion, and optionally some cornerstone data and a description, click the *Add Rule* button to add the rule to the tree. The new node will be displayed at the selected position on the tree with the relevant coloured node icon indicating whether it is a true or false node of its parent. New potential node add-points will also be displayed. See Figure 8.26 for an example of a newly created tree that has several nodes added.

Repeat the add rule procedure for however many rule nodes you wish to add by clicking on the appropriate

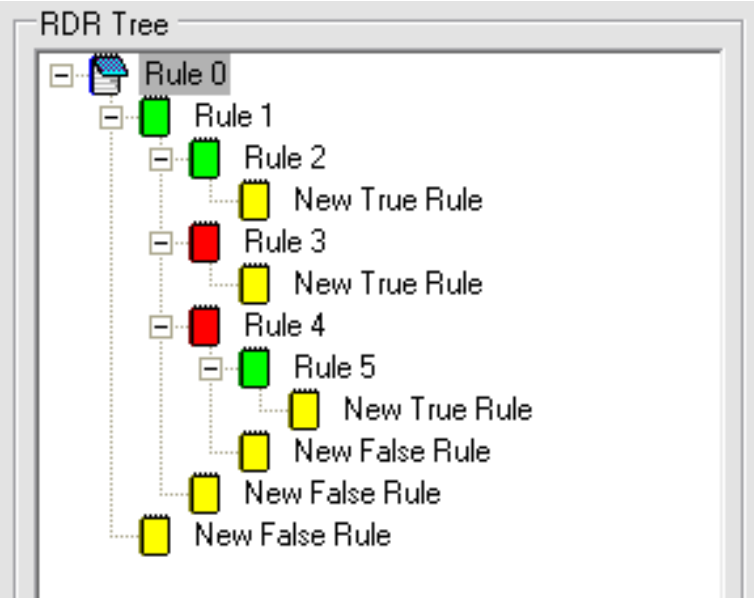


Figure 8.26: Creating a New Rule Tree

yellow node (note that when you click on a node other than yellow, its stored details are displayed in the various form inputs).

TIPS:

- If the number of nodes starts to get a little confusing, you can check which node is the parent of the selected node by looking at its id in the Selected Node panel.
- If you start to add details for a new node then change your mind about adding it, simply click on any other node (rather than clicking on the *Add Rule* button) - doing that will immediately discard any input data values. **Don't** click Cancel - that closes the entire form without saving anything (see below).

When you are done adding nodes, click the *Add Tree* button to add the tree you have just created to the tree set selected (via the selected *Rule Type* and *Task Name* lists).

IMPORTANT: Once you have added the newly created tree to the selected tree set using the *Add Tree* button, you will no longer be able to add nodes to the tree via the *New Rule Set* form. This is to protect the integrity of the rule set. Since each subsequent rule will be added because of an exceptional case or where the selected worklet does not fit the context of a case, the preferred method is to create the base rule set and then add rules as they become necessary via the *Add Rule* form as described earlier. In this way, added rules are based on real case data and so are guaranteed to be valid. In a similar vein, there is no option to modify or delete a rule node within a tree once the tree has been added to the rule set, since to allow it would destroy the integrity of the rule set, because the validity of child rule nodes depend on the conditions of their parents.

When a tree is added to the tree set:

- If it is a case-level tree, the rule type that the tree represents will be removed from the *Rule Type* list. That is, the rule type now has a tree defined for it and so is no longer available for selection on the *New Rule* form.
- If it is an item-level tree, the task name that the tree represents will be removed from the *Task Name* list. That is, the task now has a rule tree defined for it (for the selected rule type) and so is no longer available.

- If it is an item-level tree, and all tasks now have trees defined for them for the selected rule type (i.e. this was the final task of the specification for which a tree has been defined), the rule type that the tree represents will be removed from the *Rule Type* list.

This approach ensures that rule trees can only be added where there are currently no trees defined for the selected specification.

Once the tree is added, the form resets to allow the addition of another new tree as required, by repeating the process above for a new rule type (or rule type/task name for item-level trees).

After you have completed adding trees, click the *Save & Close* button to save all the additions to the rule set file. The Rules Editor will return to the main form where the additional trees will immediately be able to be browsed.

IMPORTANT: No additions will be actually saved until the *Save & Close* button is clicked - this is to allow you the option to discard all additions, if you wish, by clicking the *Cancel* button. That is, cancelling returns to the main Editor form and discards **ALL** additions for the session; *Save & Close* returns to the main form and saves all additions.

8.5.8 Drawing a Conclusion Sequence

As mentioned in the *Adding a New Rule* section, adding a conclusion to a Selection rule is simply a matter of choosing a worklet from the list or creating a new worklet in the YAWL editor. However, when adding a conclusion for a rule type other than *Selection* (i.e. an exception rule type), an exception handling sequence needs to be defined that will manage the handling process invoked by the rule. The earlier section on the Exception Service detailed the various actions that make up the available set of exception handling 'primitives or tasks that may be sequenced to form an entire handling process.

The *Draw Conclusion* dialog makes the process of defining an exception handling sequence easier by allowing you to create the sequence graphically. Simply select the appropriate primitive from the toolbox on the left, and then click on the drawing canvas to place the selected primitive. Figure 8.27 shows an example of the *Draw Conclusion* dialog.

Use the *Arc Tool* to define the sequence order. First, select the *Arc Tool* in the toolbox, then click and hold on the first node, drag the mouse pointer until it is over the next node in the sequence, then release the mouse. For a conclusion to be valid (and thus allowed to be saved) there must be a direct, unbroken path from the start node to the end node (the start and end nodes are always displayed on the canvas). Also, the conclusion will be considered invalid if there are any nodes on the canvas that are not attached to the sequence when *Save* is attempted.

Use the *Select Tool* to move placed primitives around the canvas. First, select the *Select Tool* in the toolbox, then click and drag a primitive to a new location.

The *Align* button will immediately align the nodes horizontally and equidistantly between the start and end nodes (as in Figure 8.27).

The *Clear* button will remove all added nodes to allow a restart of the drawing process.

The *Cancel* button discards all work and returns to the previous form.

The *Save* button will save the conclusion and return to the previous form (as long as the sequence is valid).

To delete a primitive from the canvas, right click on the primitive and select *Delete* from the popup menu.

The *Compensate* primitive will, when invoked at runtime, execute a worklet as a compensation process as part of the handling process. To specify which worklet to run for this sequence, right click on the *Compensate* primitive and select *Define Worklet* from the popup menu. The *Choose Worklet* dialog will appear (identically to the *Selection* conclusion process) allowing the selection of an existing worklet or the definition of a new worklet to run as a compensatory process. Select the appropriate worklet to add it to the compensatory primitive. Note that a sequence will be considered invalid if it contains a *Compensate* primitive for which a worklet has not yet been defined.

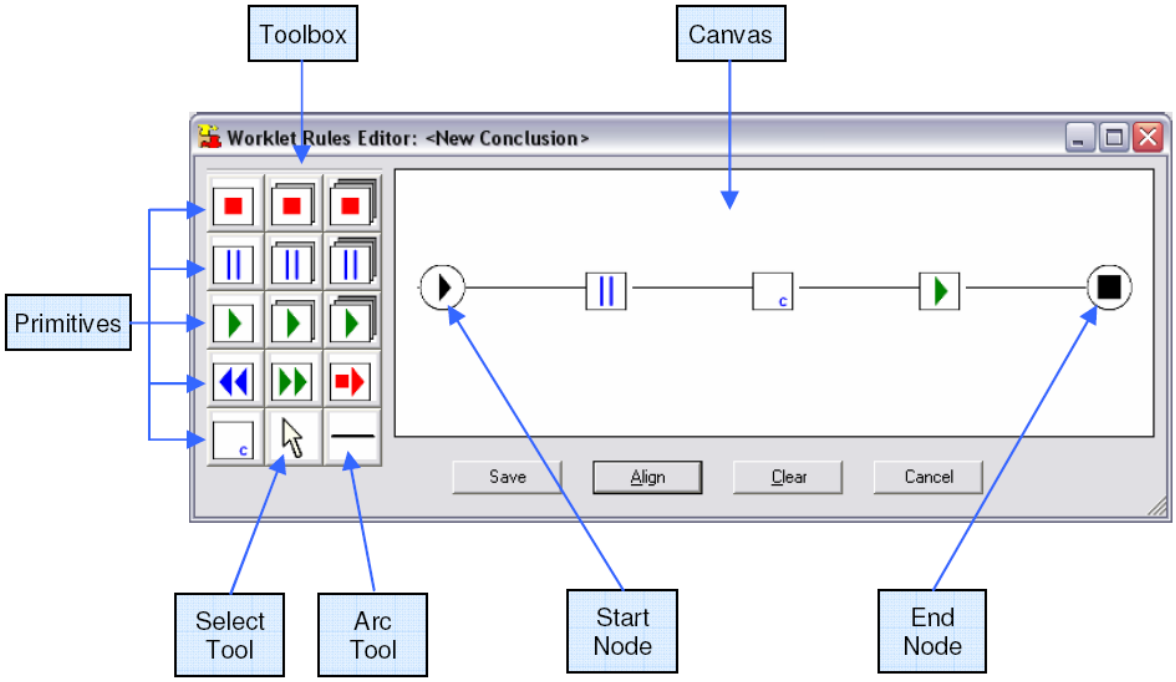


Figure 8.27: The Draw Conclusion Dialog

The primitives *SuspendAllCases*, *RemoveAllCases* and *ContinueAllCases* may be limited to ancestor cases only by right-clicking on primitives of those kinds and selecting *Ancestor Cases Only* from the popup menu. Ancestor hierarchies occur where a worklet is invoked for a case, which in turn invokes a worklet, and so on. When a primitive is limited to ancestor cases, it applies the primitives action to all cases in the hierarchy from the current case back to the original parent case, rather than all running cases of the specification.

IMPORTANT: No validation is done for the defined sequence, besides that described above. It is up to the designer of the sequence to ensure it makes sense (for example, that it doesnt try to continue a case it has previously removed).

When a valid sequence is saved, you will be returned to the previous form (i.e. either the *Add Rule* or *New Rule* form depending on where you are in the Editor). The conclusion will be displayed textually as a sequential list of tasks (Figure 8.28, for example).

Figure 8.28: A Conclusion Sequence shown as Text (detail)

8.6 Walkthrough - Using the Worklet Service

The worklet repository that comes with the Worklet Service release contains a number of example specifications with worklet-enabled tasks, each with an associated rule set and a number of associated worklets. This section will step through the execution of several of these examples. The first two examples feature

the Selection Service; the remainder the Exception Service. Knowledge of how to use the YAWL system is assumed. Before we begin, make sure the Worklet Service is correctly installed and operational, and then log into the YAWL system.

A. Selection: Worklet-Enabled Atomic Task Example

The *Casualty Treatment* specification used in the previous sections of this manual is an example of a specification that contains an atomic task (called *Treat*) that is worklet selection-enabled. We'll run a complete instance of the example specification to see how worklet selection operates.

Log on to YAWL with a user that has administrator or 'can manage cases' privileges. Navigate to the *Case Mgt* page and upload the *Casualty Treatment* specification from the *worklets* folder of the worklet repository. Then, launch a *Casualty Treatment* case from the same page.

The case begins by requesting a patient id and name - just enter some data into each field then click *Submit* (Figure 8.29).

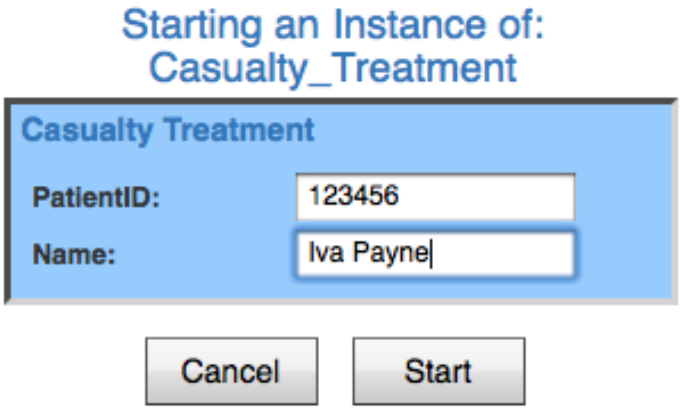


Figure 8.29: Launching a Casualty Treatment Case (detail)

Go to the *Work Queues* page, and the first task in the case (*Admit*) will be listed as an offered workitem. Make a note of the case number. *Accept & Start* the *Admit* workitem.

The *Admit* workitem simulates an admission to the Casualty department of a hospital, where various initial checks are made of the patient. You'll see that, in addition to the patient name and id specified when the case started, there are a number of fields containing some medical data about the patient. Each field has some default data (to save time), but you may edit any fields as you wish (Figure 8.30). When done, click the *Complete* button.

Go back to the *Work Queues* page and start the next workitem, *Triage*. The *Triage* task simulates that part of the process where a medical practitioner asks a patient to nominate their symptoms. You'll see that the patient's name and id have again been displayed for identification purposes, in addition to five fields which approximate the medical problem. One field should be set to *True*, the others to *False*.

Lets assume the patient has a fever. Set the *Fever* field to *True*, the rest to *False*, and then click the *Complete* button (Figure 8.31).

There is nothing special about the first two tasks in the process; they are standard YAWL tasks and operate as expected. However, the next task, *Treat*, has been associated (using the YAWL Editor) with the Worklet Service. The Treat task simulates that part of the process that follows the collection of patient data and actually treats the patient's problem.

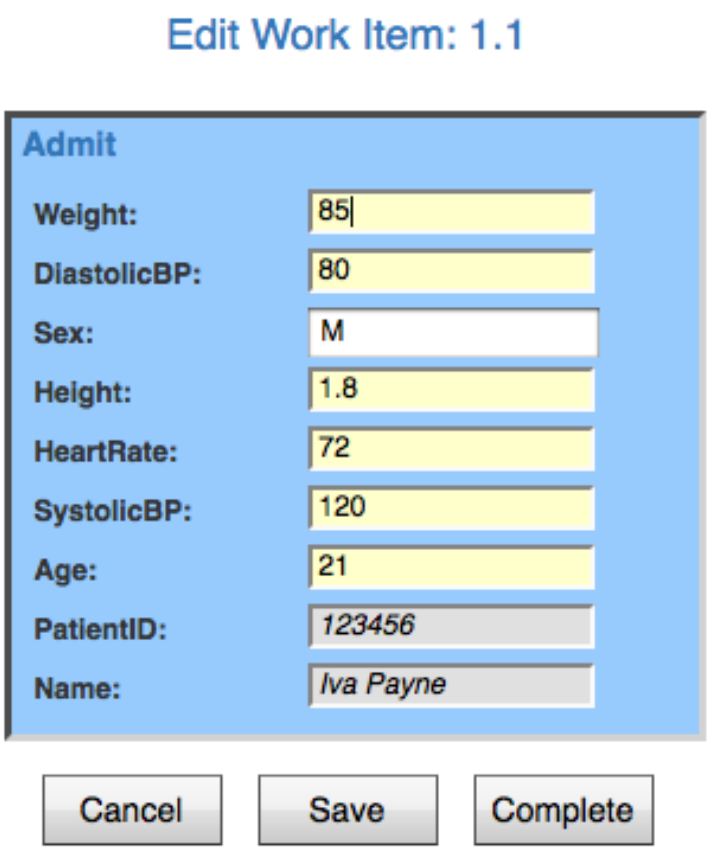


Figure 8.30: Editing the *Admit* Workitem (detail)

Of course, there are many medical problems a patient may present with, and so there are just as many treatments, and some treatment methods are vastly different to others. In a typical workflow process, this is the part of the process where things could get very complicated, particularly if we tried to build every possible treatment as a conditional branch into the process model.

The Worklet Service greatly simplifies this problem, by providing an extensible repertoire of discrete workflow processes (worklets) which, in this example, each handle the treatment of a particular medical problem. By examining the case data collected in the earlier tasks, the Worklet Service can launch, as a separate case, the particular treatment process for each case.

This method allows for a simple expression of the task in the 'parent' process (i.e. a single atomic *Treat* task signifies the treatment of a patient, whatever the eventual treatment process may be) as well as the ability to add to the repertoire of worklets at any time as new treatments become available, without having to modify the original process.

When the *Triage* workitem is submitted, the next task in the process, *Treat*, becomes enabled. Because it is worklet-enabled, the Worklet Service is notified. The Service checks to see if there is a set of rules associated with this workitem, and if so the service checks out the workitem.

When this occurs, the YAWL Engine marks the workitem as executing (externally to the Engine) and waits for the workitem to be checked back in. In the meantime, the Worklet Service uploads the relevant specification for the worklet chosen as a substitute for the workitem and launches a new case for the specification. When the worklet case completes, the Worklet Service is notified of the cases completion, and the service then checks the original workitem back into the Engine, allowing the original process to continue.

We have completed editing the *Triage* workitem and clicked the *Complete* button. Go to the *Work Queues*

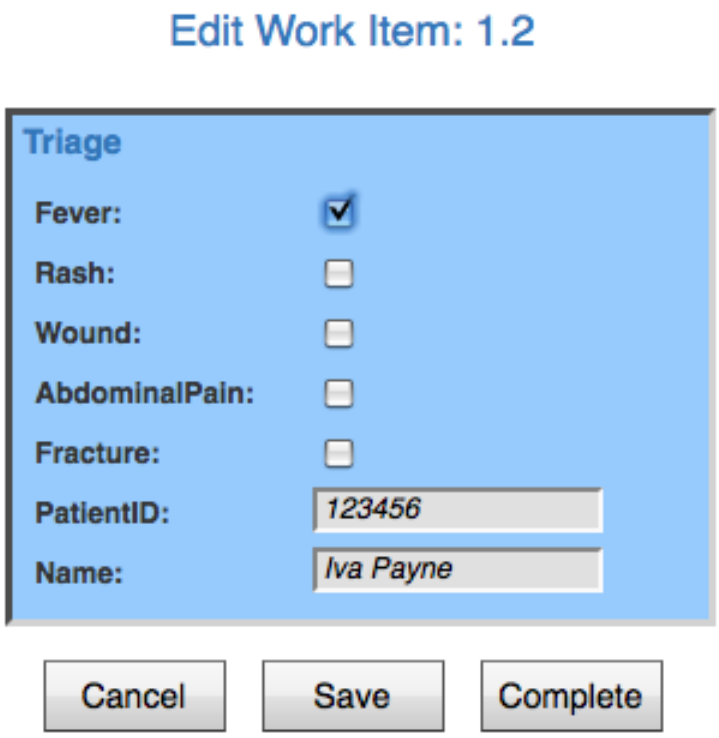


Figure 8.31: Editing the *Triage* Workitem (detail)

page. Instead of seeing the next workitem listed (i.e. *Treat*), we see that *Test Fever*, the first workitem in the *TreatFever* process, is listed in its place (Figure 8.32). The *TreatFever* process has been chosen by the Worklet Service to replace the *Treat* workitem based on the data passed to the service.

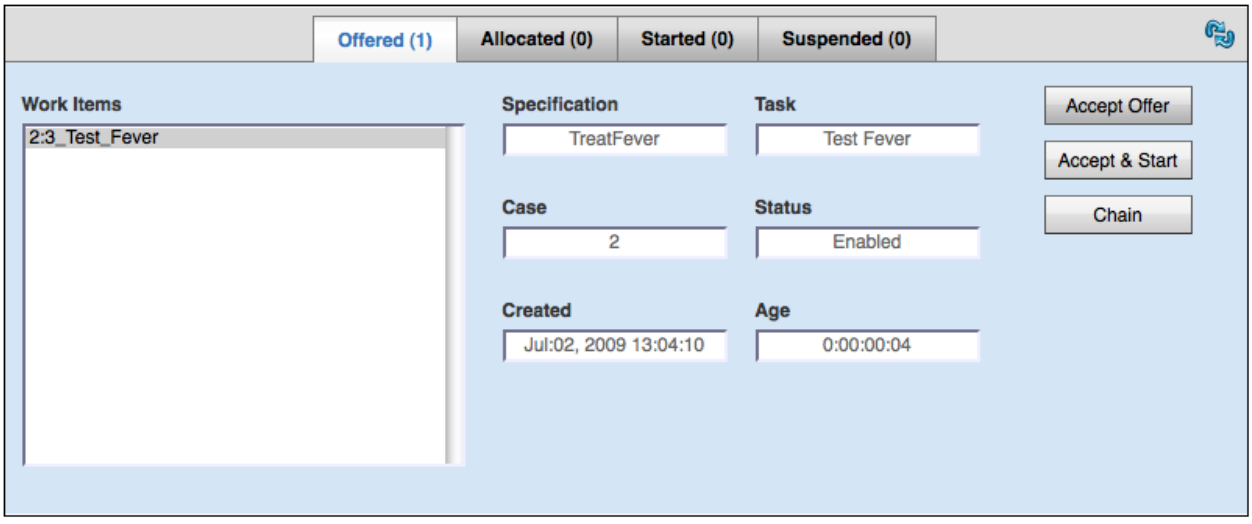


Figure 8.32: New Case Launched by the Worklet Service

Note that the case id for the Test Fever workitem is different to the case id of the parent process. Worklets run as completely different cases to the parent process, but the Worklet Service keeps track of which worklets

are running for which parent cases. Go to the *Case Mgt* page to see that a *Casualty Treatment* case is still running, and that the *TreatFever* specification has been loaded and it also has a case running (Figure 8.33).

Go back to the *Work Queues* page and start the *Test Fever* workitem. The *Test Fever* workitem has mapped the patient name and id values, and the particular symptom - fever - from the *Treat* workitem checked out by the Worklet Service. In addition, it has a *Notes* field where a medical practitioner can enter observations about the patient's condition (Figure 8.34). Enter some information into the *Notes* field, and then complete it.

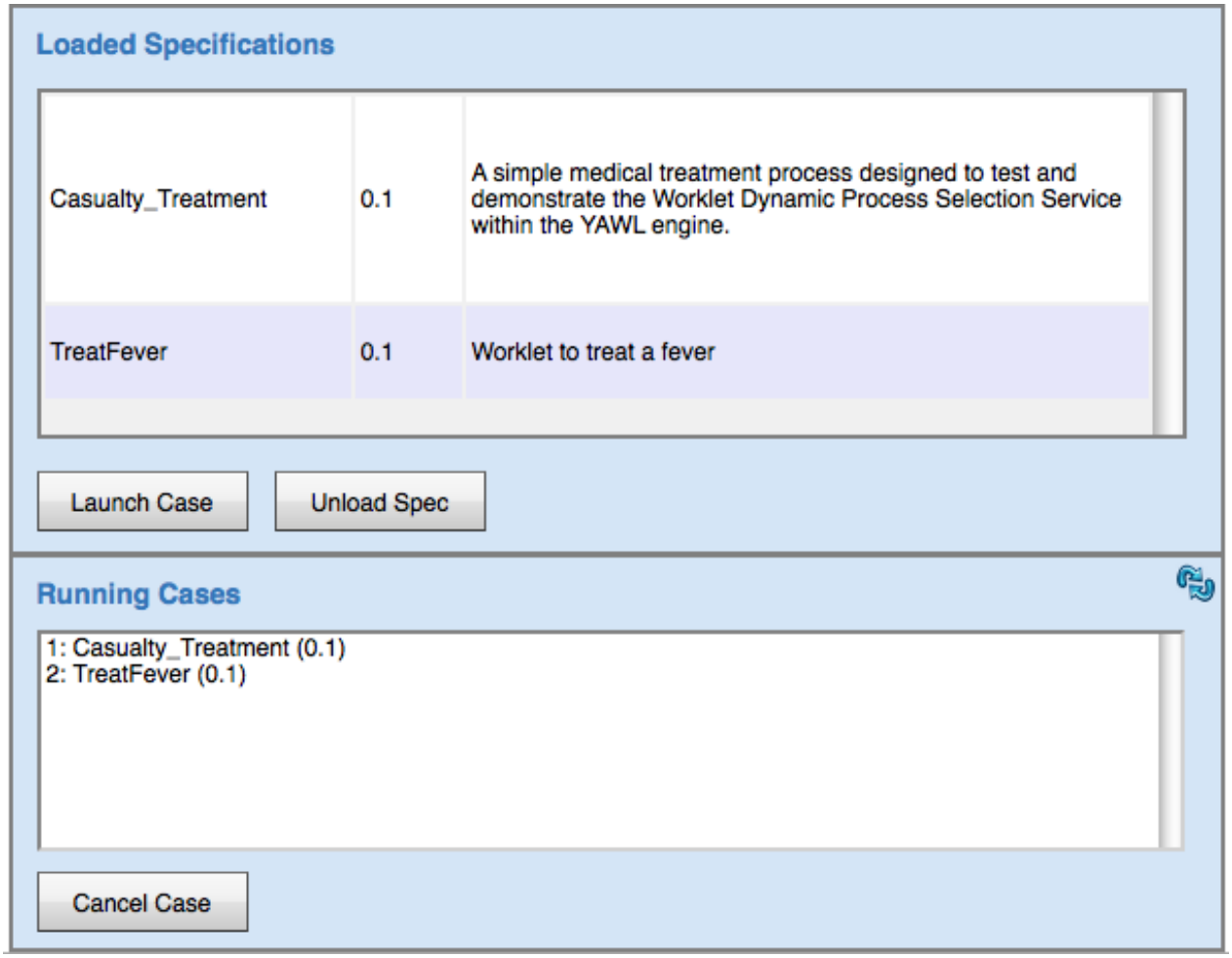


Figure 8.33: TreatFever Specification Uploaded and Launched

Start the next workitem, *Treat Fever*, and then edit it. This workitem has two additional fields, Treatment and Pharmacy, where details about how to treat the condition can be entered (Figure 8.35). Enter some data here, and then complete it.

When the *Treat Fever* workitem is submitted, the worklet case is completed. The Worklet Service maps the output data from the worklet case to the matching variables of the original *Treat* workitem, then checks that workitem back in, effectively completing it and allowing the next workitem in the *Casualty Treatment* process, *Discharge*, to execute.

Go to the *Work Queues* page, and you'll see that the *Discharge* workitem is available (Figure 8.36). Edit it to see that the data collected by the *TreatFever* worklet has been mapped back to this workitem. Submit it to complete the case.

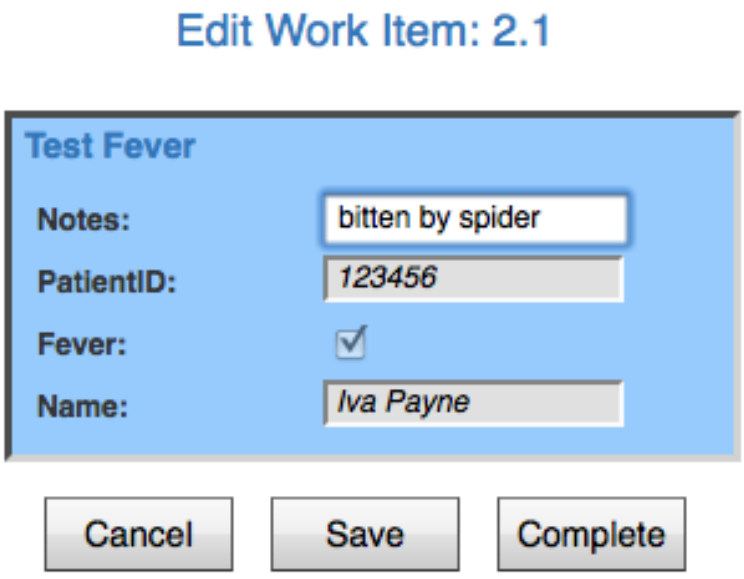


Figure 8.34: Test Fever Workitem (detail)

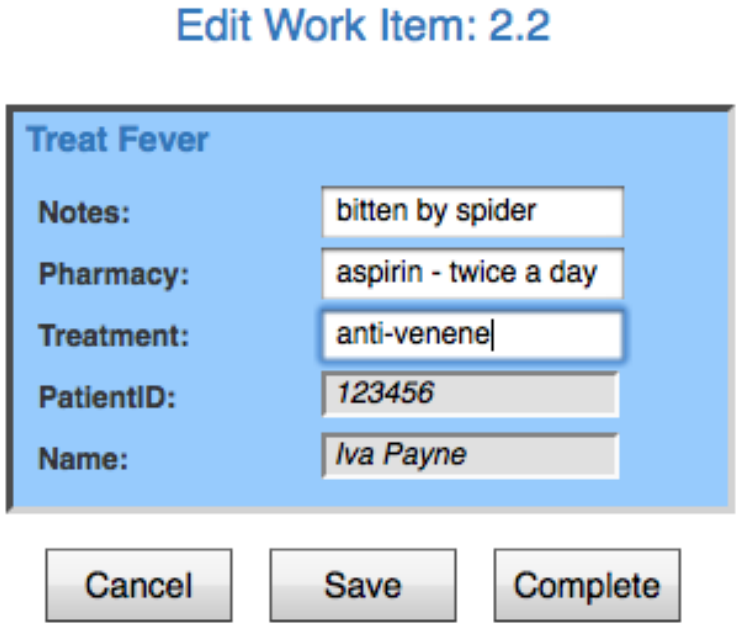


Figure 8.35: Treat Fever Workitem (detail)

B. Selection: Worklet-Enabled Multiple Instance Atomic Task Example

This walkthrough takes the *List Maker* example from the YAWL Editor User Manual and worklet-enables the *Verify List* task to show how multiple instance atomic tasks are handled by the Worklet Selection Service.

The specification is called *wListMaker*. The only change made to the original List Maker specification was to associate the *Verify List* task with the Worklet Service using the YAWL Editor. Figure 8.37 shows the specification.

Go to the *Case Mgt* page and upload the *wListMaker* specification from the worklets folder of the worklet

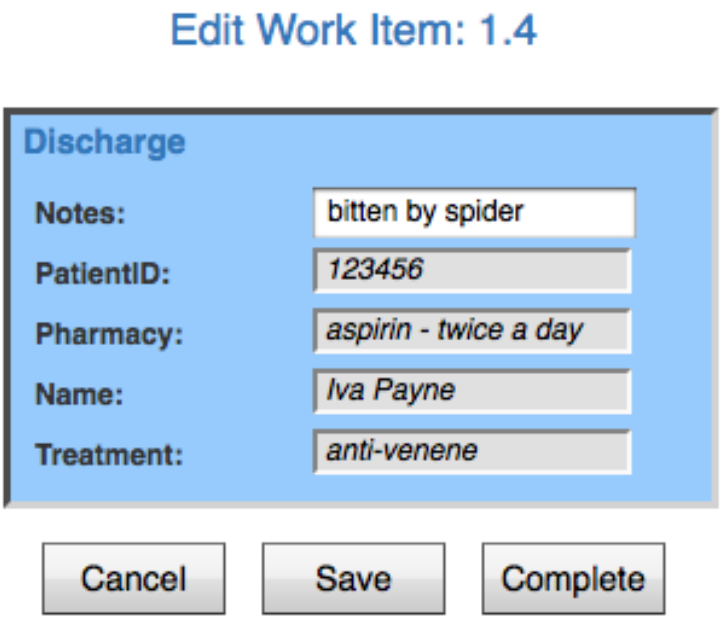


Figure 8.36: Discharge Workitem with Data Mapped from *TreatFever* Worklet

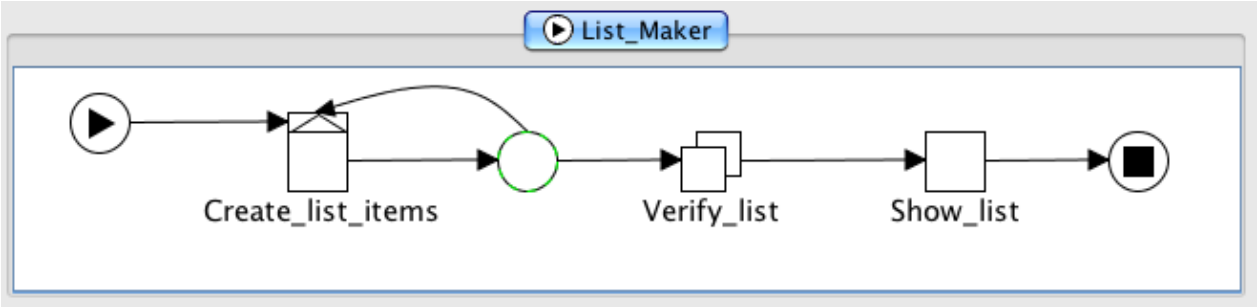


Figure 8.37: The *wListMaker* Specification

repository. Then, launch an instance of *wListMaker*.

When the case begins, enter three values for the *Bob* variable, as shown in Figure 8.38 - you will have to click the *add* (+) button twice to get three input fields. Make sure you enter the values "one", "two" and "three" (without the quotes and in any order). Complete the form.

Start and edit the *Create List Items* workitem. Since the values have already been entered there is no more to do here, so click the *Complete* button to continue.

The next task is *Verify List*, which has been associated with the Worklet Service. Since this task is a multiple-instance atomic task, three child workitem instances of the task are created, one for each of the *Bob* values entered previously. The Worklet Service will determine that it is a multiple instance atomic task and will treat each child workitem instance separately, and will launch the appropriate worklet for each based on the data contained in each. Since the data in each child instance is different in this example, the Worklet Service starts three different worklets, called *BobOne*, *BobTwo* and *BobThree*. Each of these worklets contains only one task.

Go to the *Work Queues* page. There are three workitems listed, each one the first workitem of a separate case (see Figure 8.39).

Figure 8.38: Start of *wListMaker* Case with Three 'Bob' Values Entered (detail)

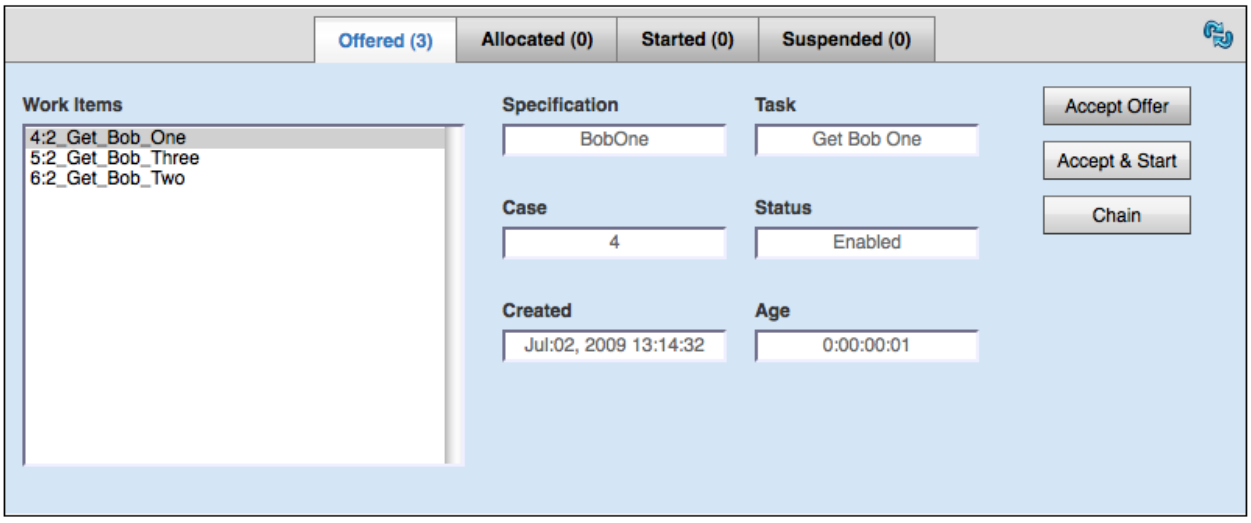


Figure 8.39: Workitems from each of the three Launched Worklet Cases

Go to the *Case Mgt* page to see that the *BobOne*, *BobTwo* and *BobThree* specifications have been uploaded and launched by the Worklet Service as separate cases (Figure 8.40 - note the case numbers).

Go back to the *Work Queues* page and check out all three workitems. Edit each of the *Get_Bob* workitems, and modify the values as you wish - for this walkthrough, we'll change the values to "one - five", "two -

six" and "three - seven" respectively.

As you edit and complete each *Get_Bob* workitem, the corresponding *Verify List* workitem from the parent instance is automatically checked in to the Engine by the Worklet Service. Since the *Bob* worklets contains only one task, editing and completing this workitem also completes the worklet case.

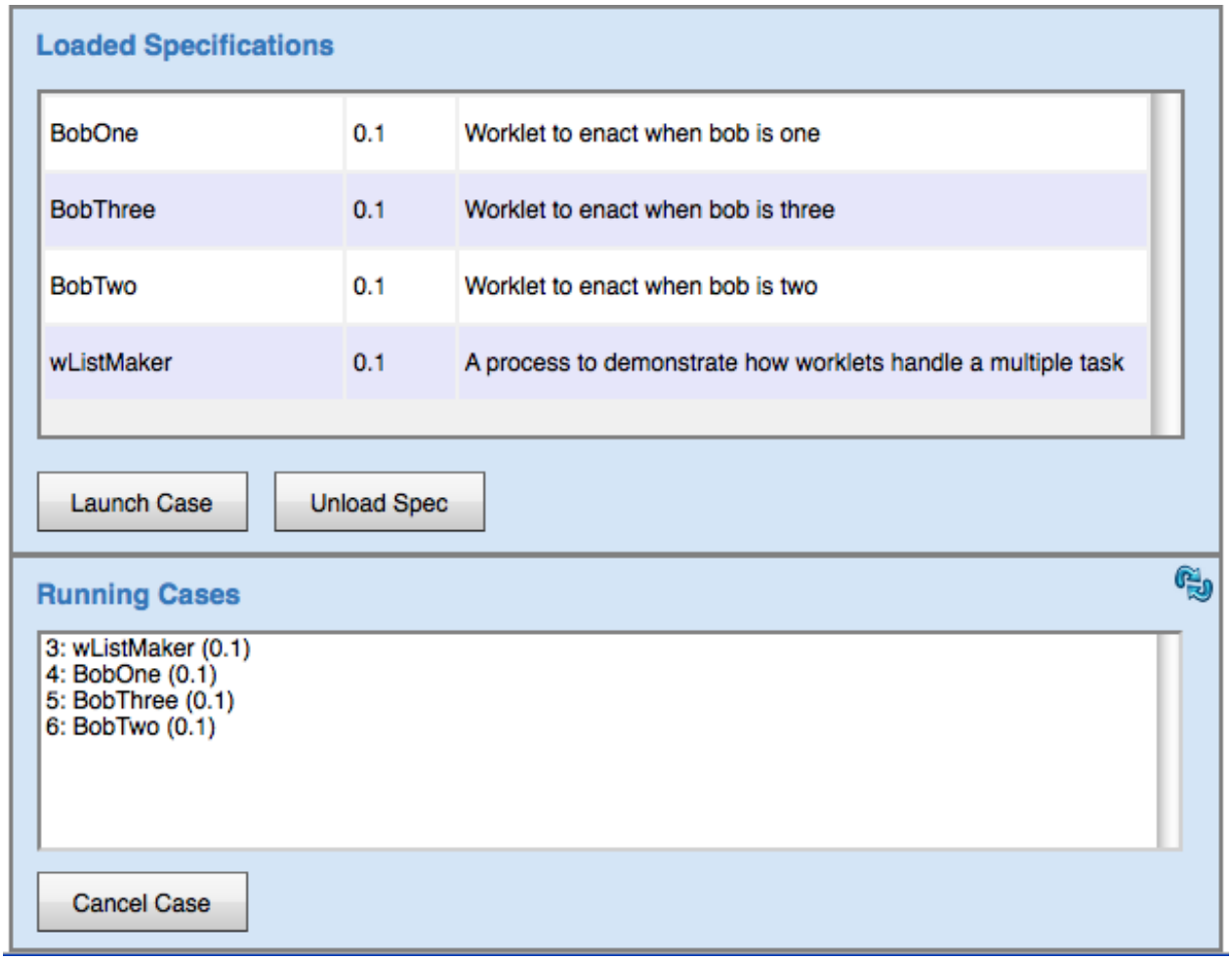

Loaded Specifications
BobOne 0.1 Worklet to enact when bob is one
BobThree 0.1 Worklet to enact when bob is three
BobTwo 0.1 Worklet to enact when bob is two
wListMaker 0.1 A process to demonstrate how worklets handle a multiple task
Launch Case
Unload Spec
Running Cases
3: wListMaker (0.1)
4: BobOne (0.1)
5: BobThree (0.1)
6: BobTwo (0.1)
Cancel Case

Figure 8.40: 'Bob' Specifications Loaded and Launched by the Worklet Service

After the third workitem has been edited and completed, and so the third *Verify List* workitem is checked back into the Engine by the Worklet Service, the Engine determines that all the child items of the *Verify List* workitem has completed and so the original process continues to its final workitem, *Show List*.

Start and edit the *Show List* workitem to show the changes made in each of the *Get_Bob* worklets have been mapped back to the original case (Figure 8.41).

C. Exception: Constraints Example

This walkthrough uses a specification called *OrganiseConcert* to demonstrate a few features of the Worklet Exception Service. The *OrganiseConcert* specification is a very simple process modelling the planning and execution of a rock concert. Figure 8.42 shows the specification as it appears in the YAWL Editor.

First, ensure the Exception Service is enabled (see Section 8.1.3 for details). Navigate to the YAWL *Case Mgt* page and upload the *OrganiseConcert* specification from the worklets folder of the worklet repository. Then,

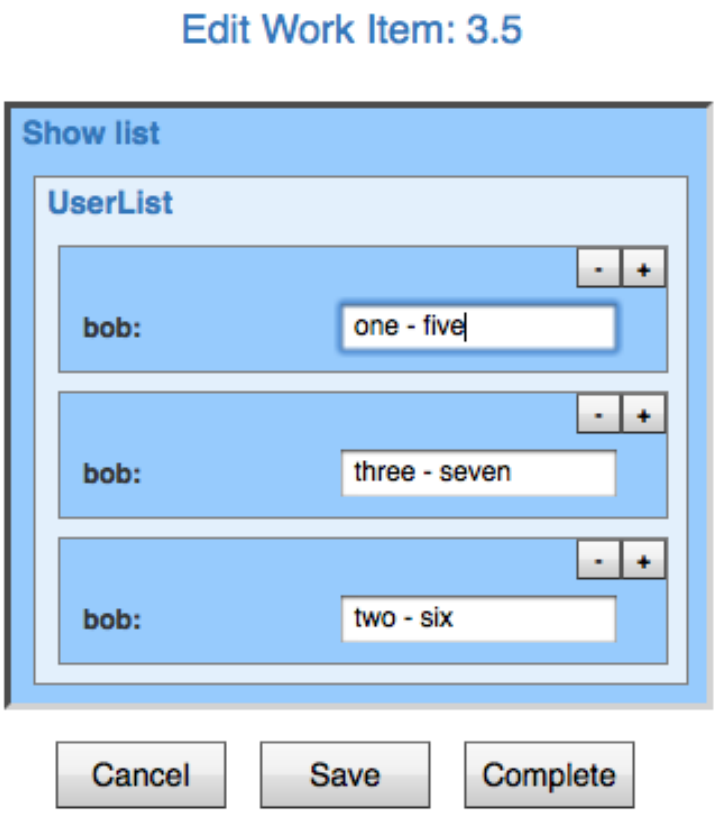


Figure 8.41: The Show List Workitem Showing the Changes to the Data Values

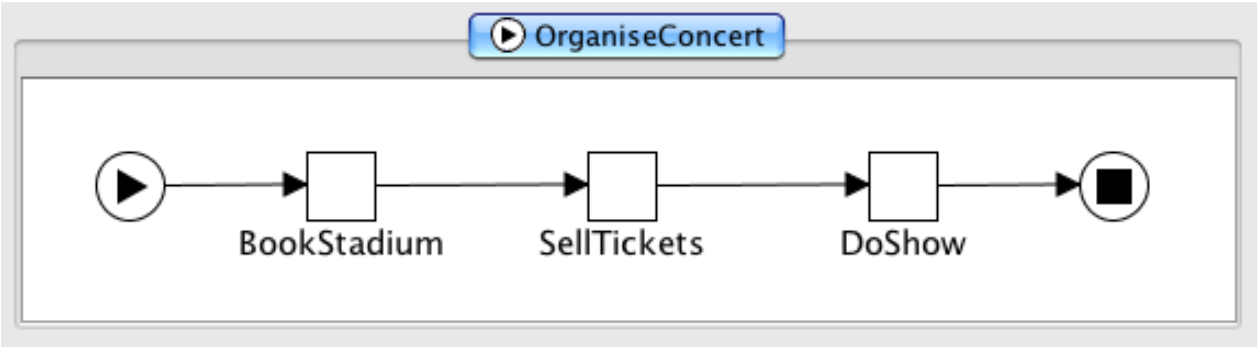


Figure 8.42: The *OrganiseConcert* Specification

launch an *OrganiseConcert* case.

As soon as the Engine launches the case, it notifies the Exception Service via a *PreCaseConstraint* event. If the rule set for *OrganiseConcert* contains a rule tree for pre-case constraints, that tree will be queried using the initial case data to determine whether there are any pre-constraints not met by the case. In this example, there are no pre-case constraint rules defined, so the notification is simply ignored.

Tip: To follow what is happening, watch the log output in the Tomcat command window (or the contents of the log file *catalina.out* in Tomcat's *logs* folder - both the exception and selection services log all interactions between themselves and the Engine to the Tomcat window and to a log file (found in the logs folder of your Tomcat installation). See Appendix 8.8 of this manual for a sample log output for this walkthrough.

Pre-case constraints can be used, amongst other things, to ensure case data is valid or within certain ranges

before the case proceeds; can be used to run compensatory worklets to correct any invalid data; or may even be used to cancel the case as soon as it starts (in certain circumstances). As a trivial example of the last point, launch an instance of the *Casualty Treatment* specification discussed in Walkthrough A, and enter "smith" for the patient name when the case starts. The *Casualty Treatment* rule set contains a pre-case constraint rule to cancel the case if the patient's name is "smith" (presumably smith is a hypochondriac!). This also serves as an example of exception rules and selection rules being defined within the same rule set.

Directly following the pre-case event, the Engine notifies the Service of a *PreItemConstraint* for the first workitem in the case (in this case, *Book Stadium*). The pre-item constraint event occurs immediately the workitem becomes enabled (i.e. ready to be checked out or executed). Like pre-case constraint rules, pre-item rules can be used to ensure workitems have valid data before they are executed. The entire set of case data is made available to the Exception Service - thus the values of any case variables may be queried in the ripple-down rules for any exception type rule. While there are pre-item constraint rule trees defined in the rule set, there are none for the *Book Stadium* task, so this event is also ignored by the service.

The *Book Stadium* workitem may be started in the normal fashion. This workitem captures the seating capacity, cost and location of the proposed rock concert. These may be changed to any valid values, but for the purposes of this example, just accept the default values as given (Figure 8.43).

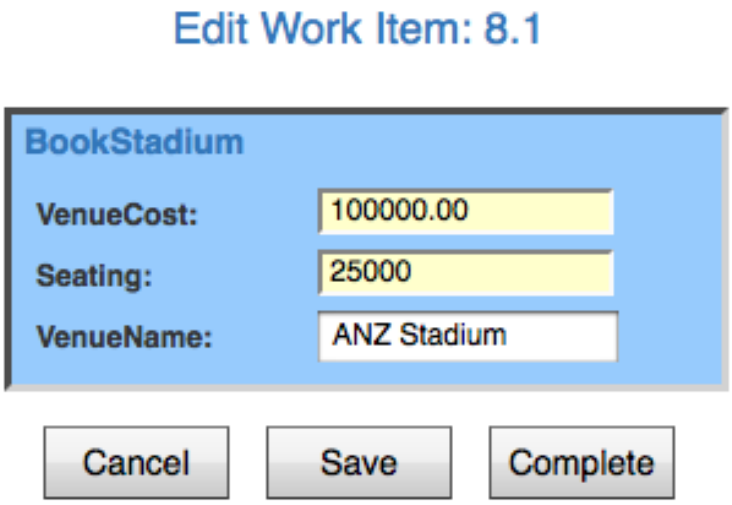


Figure 8.43: The Book Stadium Workitem (detail)

When the workitem is submitted, a *PostItemConstraint* event is generated for it by the Engine. There are no post-item constraint rules for this workitem, so again the event is just ignored. Then, a pre-item constraint notification is received for the next workitem (*Sell Tickets*). This workitem records the number of tickets sold, and the price of each ticket. Enter a price of $100 per ticket, and 12600 as the number of tickets sold, and then complete the workitem (Figure 8.44).

Notice that the entered number of tickets sold (12600) is slightly more than 50% of the venue's seating capacity (25000). The next workitem, *Do Show*, does have a pre-item constraint rule tree, and so when it becomes enabled, the rule tree is queried. The effective composite rule for *Do Show*s pre-item tree (as viewed in the Rules Editor), is:

In other words, when *Do Show* is enabled and the value of the case data attribute "TicketsSold" is less than 75% of the seating capacity of the venue, we would like to suspend the workitem, run the compensatory worklet *ChangeToMidVenue*, and then, once the worklet has completed, continue (or unsuspend) the workitem. Following the logic of the ripple-down rule, if the tickets sold are also less than 50% of the capacity, then we want instead to suspend the workitem, run the *ChangeToSmallVenue* worklet, and then unsuspend the workitem. Finally, if there has been less than 20% of the tickets sold, we want instead to suspend the entire case, run a worklet to cancel the show, and then remove (i.e. cancel) the case.

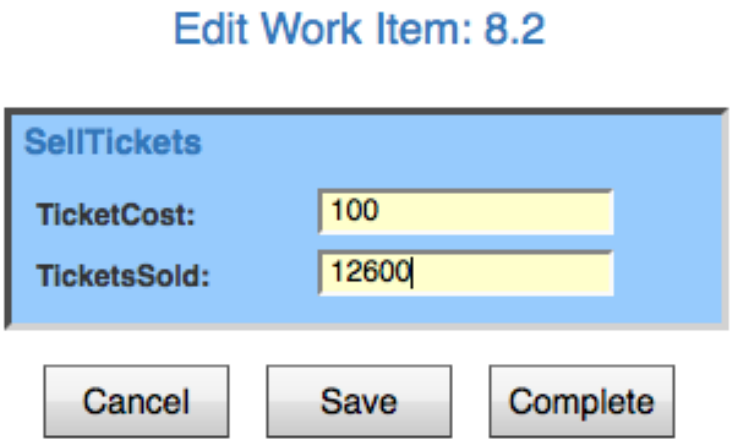


Figure 8.44: The Sell Tickets Workitem (detail)

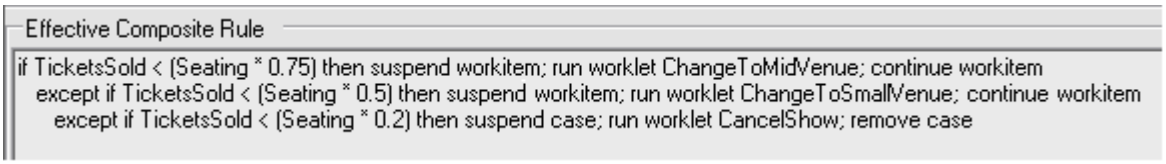

Effective Composite Rule
if TicketsSold < (Seating * 0.75) then suspend workitem; run worklet ChangeToMidVenue; continue workitem
except if TicketsSold < (Seating * 0.5) then suspend workitem; run worklet ChangeToSmallVenue; continue workitem
except if TicketsSold < (Seating * 0.2) then suspend case; run worklet CancelShow; remove case

Figure 8.45: Effective Composite Rule for Do Shows Pre-Item Constraint Tree

In this example, the first rule's condition evaluates to true, for a "Tickets Sold" value of 12600 and a seating capacity of 25000, so the child rule node on the true branch of the parent is tested. Since this child node's condition evaluates to false for the case data, the rule evaluation is complete and the last true node returns its conclusion.

The result of all this can be seen in the *Work Queues* screen of the worklist. The *Do Show* workitem is marked as "Suspended" and thus is unable to be selected for starting; while the *ChangeToMidVenue* worklet has been launched and its first workitem, *Cancel Stadium*, is enabled and may be started.

By viewing the log file, you will see that the *ChangeToMidVenue* worklet is being treated by the Exception Service as just another case, and so receives notifications from the Engine for pre-case and pre-item constraint events also.

Start *Cancel Stadium*, accept the default values, and complete. Notice that the worklet has mapped the data attributes and values from the parent case. Next, start the *Book Ent Centre* workitem - by default, it contains the data values mapped from the parent case. Since we are moving the concert to a smaller venue, change the values to match those in Figure 8.46, then complete the workitem.

The third workitem in the worklet, *Tell Punters*, is designed for the marketing department to advise fans and existing ticket holders of the change in venue.

Start the workitem. Notice that the values here are read-only (since this item is meant to be a notification only, the person assigned does not need to change any values). This is the last workitem in the worklet, so when that is completed, the engine completes the case and notifies the Exception Service of the completion, at which time the service completes the third and final part of the exception handling process, i.e. continuing or unsuspending the *Do Show* workitem so that the parent case can continue.

Back at the *Work Queues* page, the *Do Show* workitem is now shown as enabled and thus is able to be started. Check it out now and notice that the data values entered in the worklet's *Book Ent Centre* workitem have been mapped back to the parent case.

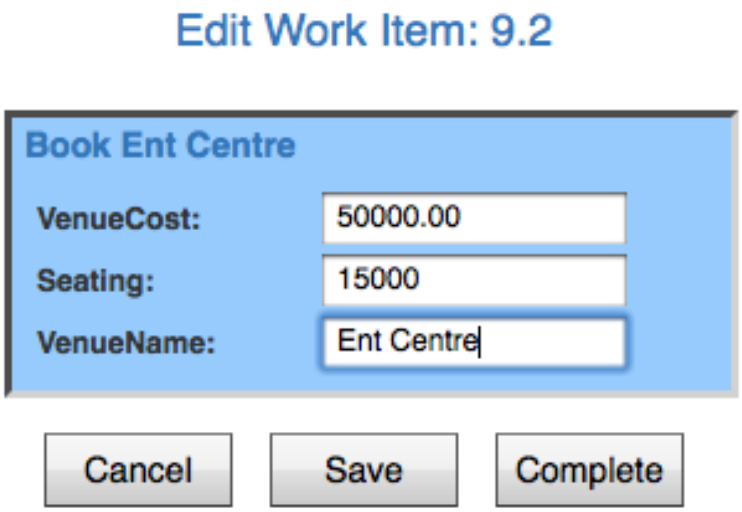


Figure 8.46: The Book Ent Centre Workitem (detail)

D. Exception: External Trigger Example

It has been stated that every case instance involves some deviation from the standard process model. Sometimes, events occur completely removed from the actual process model itself, but affect the way the process instance proceeds. Typically, these kinds of events are handled "off-system" so there is no record of them, or the way they were handled, kept for future executions of the process specification.

The Worklet Exception Service allows for such events to be handled on-system by providing a means for exceptions to be raised by users externally to the process itself. The *Organise Concert* specification will again be used to illustrate how external triggers work.

Go to the *Case Mgt* page and launch another instance of the *Organise Concert* specification. Execute and submit the first workitem.

If the Worklet Exception Service has been correctly enabled in the Resource Service, two extra buttons will appear on the *Case Mgt* page: *Raise Exception* and *Reject Worklet*[2]. To raise a case-level external exception, go to the *Case Mgt* screen, and select the *Organise Concert* case from the list of running cases, then click the *Raise Exception* button (Figure 8.47).

The *Raise Case Level Exception* screen is now displayed. This screen is a member of a set of Worklet Service add-in screens for the worklist. Before this screen is displayed, the Exception Service retrieves from the rule set for the selected case the list of existing external exception triggers (if any) for the cases specification. See Figure 8.48 for the list of case-level external triggers defined for the *Organise Concert* specification.

This list contains all of the external triggers either conceived when the specification was first designed or added later as new kinds of exceptional events occurred and were added to the rule set. Notice that at the bottom of the list, the option to add a New External Exception is provided - that option is explained in detail in Walkthrough F.

For this example, lets assume the band has requested some refreshments for backstage. Select that exception trigger and submit the form. When that exception is selected, the conclusion for that trigger's rule is invoked by the service as an exception handling process for the current case. Go to the *Work Queues* form where it can be seen that the parent case has been suspended and the first workitem of the compensatory worklet, *Organise Refreshments*, has been enabled (Figure 8.49).

Organise Refreshments informs the staff member responsible to buy a certain number of bags of M & Ms (first

[2]If the two buttons don't appear, the exception service has not been correctly enabled for the Resource Service; review the installation section at the beginning of this chapter for details on how to enable the service.

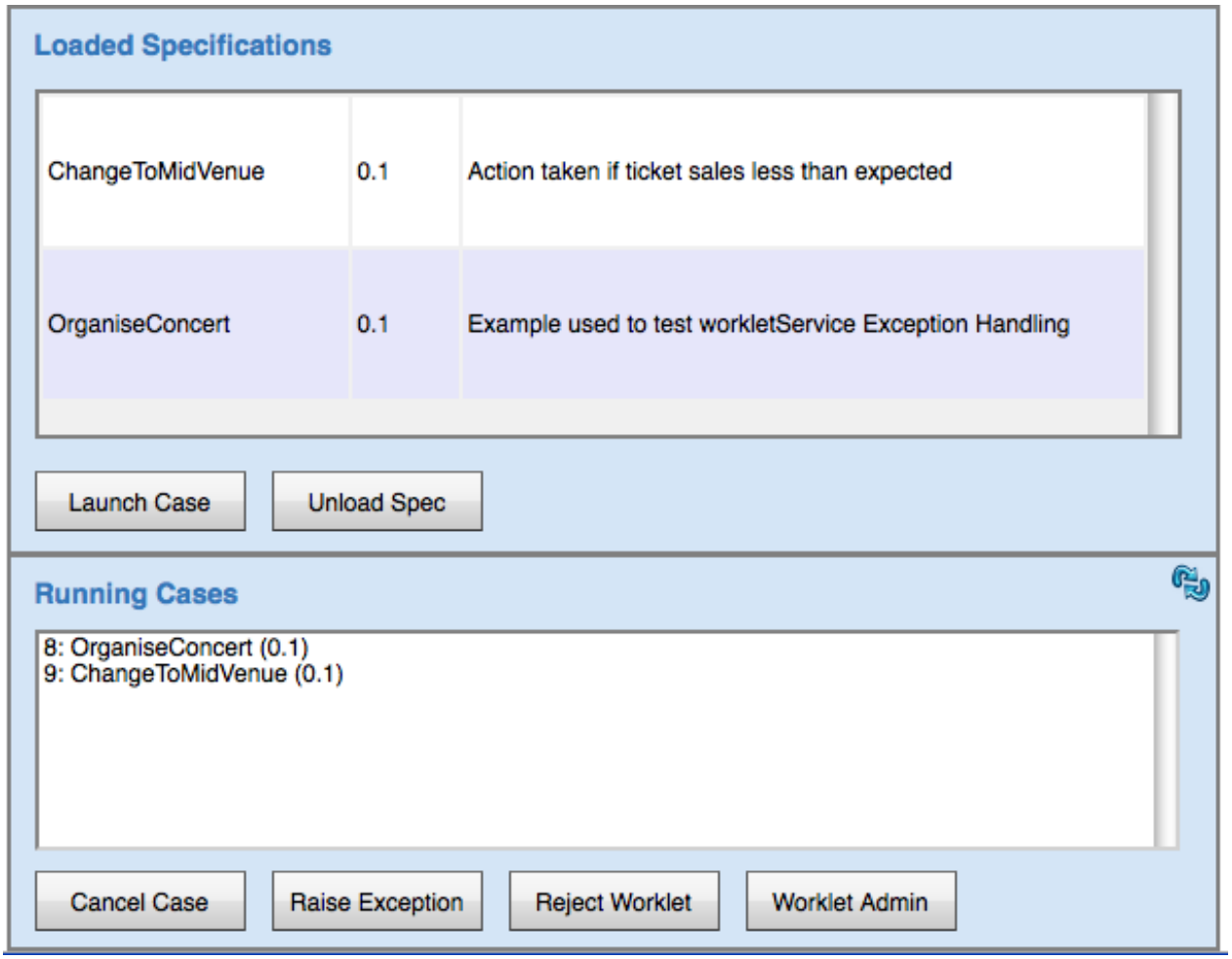


Figure 8.47: Case Mgt Screen, *OrganiseConcert* case running

workitem), then to remove all the candies except those of a specified colour, before delivering them to the venue (mapped in from the parent case). Once the worklet has completed, the parent case is continued.

Item-level external exceptions can be raised from the *Work Queue* page by selecting the relevant workitem from the list, then clicking the *Raise Exception* button at the top-right toolbar (the green 'forked arrow' within the tabbed area – see Figure 8.49). You will be taken to the *Raise Item Level Exception* screen where the procedure is identical to that described for case-level exceptions, except that the item-level external exception triggers, if any, will be displayed.

External exceptions can be raised at any time during the execution of a case - the way they are handled may depend on how far the process has progressed (via the defining of appropriate rule tree or trees).

E. Exception: Timeout Example

When a workitem has an associated timer that times out (expires), the Engine notifies the Exception Service and informs it of all the workitems running in parallel with the timed out item. Thus, rule trees can be defined to handle timeout events for all affected workitems (including the timed out item itself).

The specification *TimeoutTest3* gives an simple example of how a timeout exception may be handled (Figure 8.50). Upload the specification via the *Case Mgt* screen, and then launch the case.

The first workitem, *Fill Order*, simulates a basic purchase order for a bike. Check out the *Fill Order* workitem,

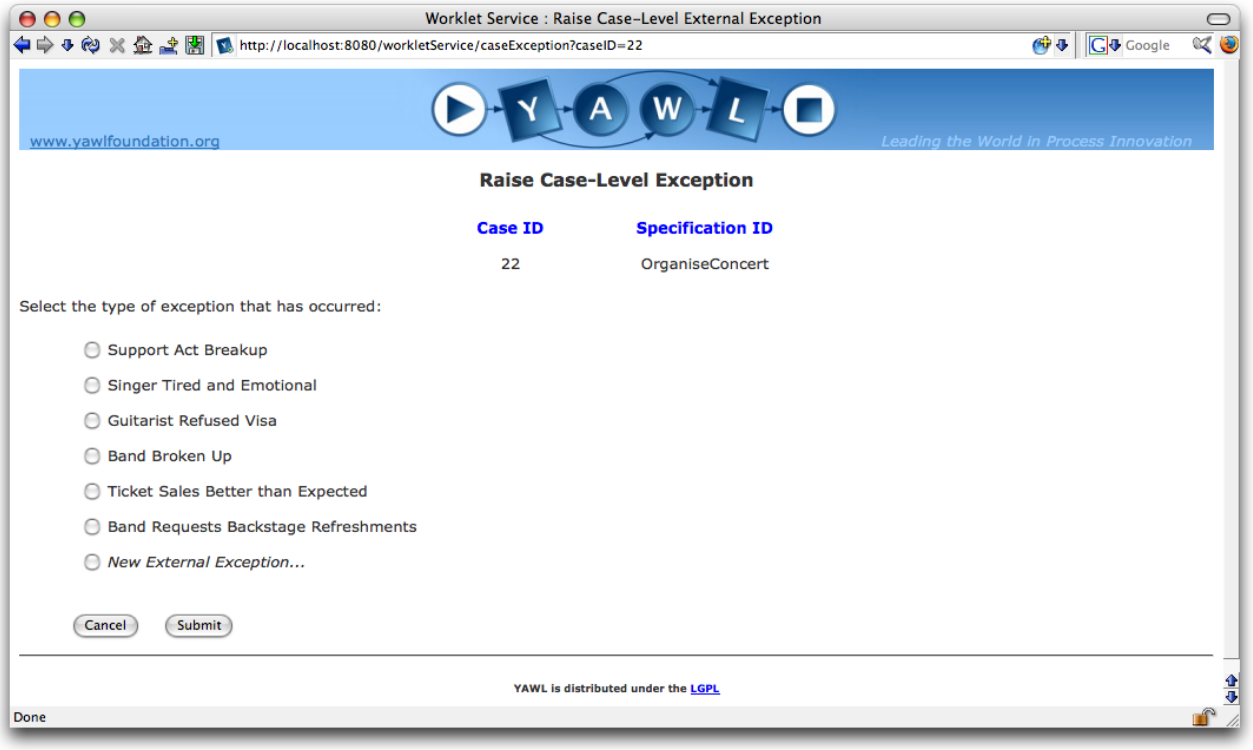


Figure 8.48: Raise Case-Level Exception Screen (Organise Concert example)

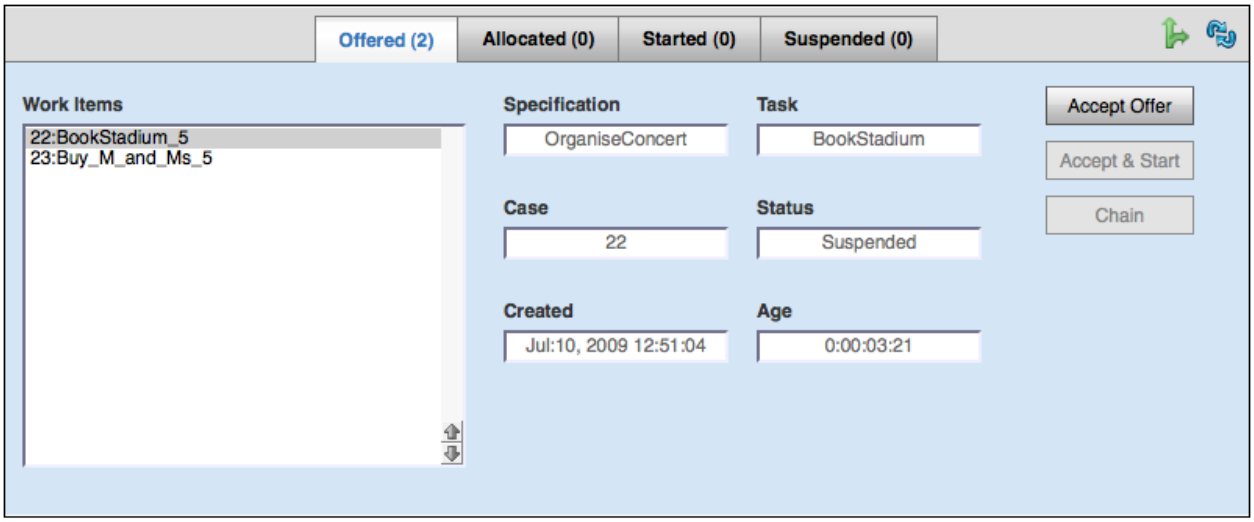


Figure 8.49: Available Work Items after External Exception Raised

accept the default values, and submit it. Once the order has been filled, the process waits for payment to be received for the order, before it is archived. The *Receive Payment* task has an associated timer, and so waits for some specified time to receive payment. For the purposes of this example, the wait time is set to 5 seconds (Figure 8.51).

While the deadline is reached, the Engine notifies the Exception Service of the timeout event. The timeout tree set is queried for the *Receive Payment* workitem. There is a tree defined for the *Receive Payment* task with a single rule (see Figure 8.52).

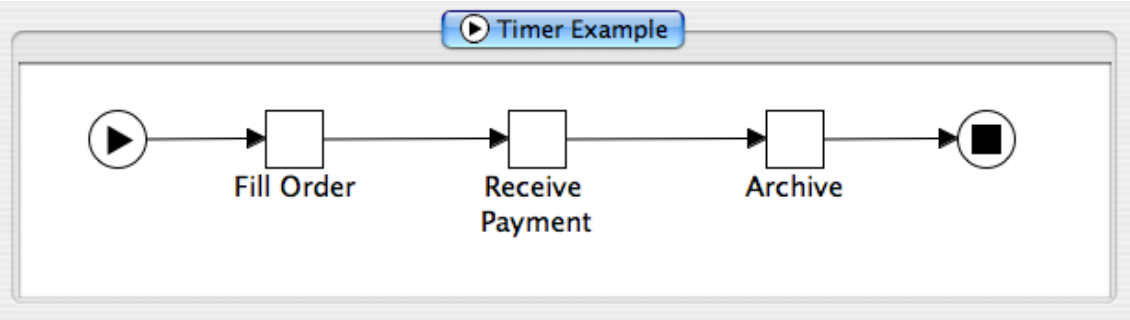


Figure 8.50: The Timeout Test 3 Specification

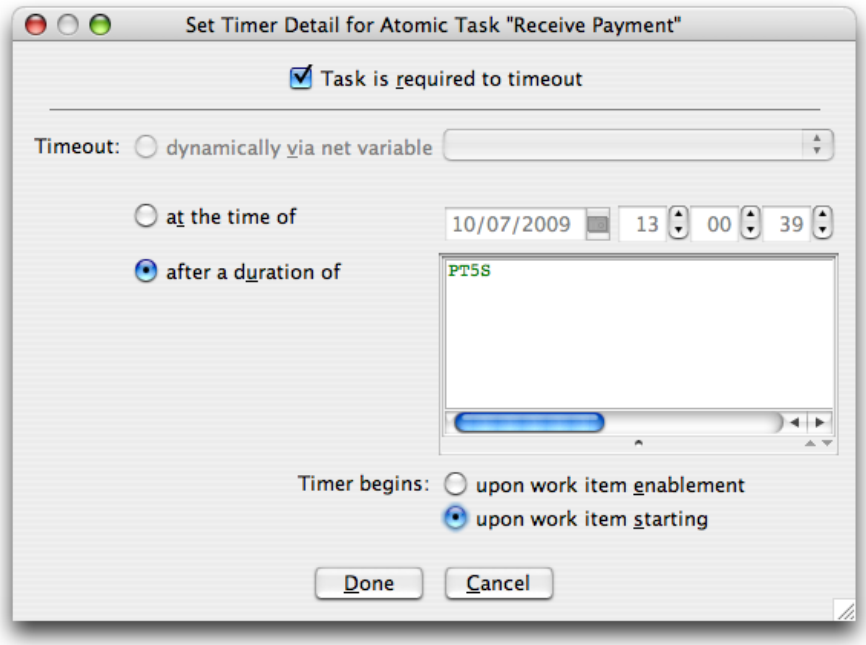


Figure 8.51: The Set Timer Detail dialog for the Receive Payment task

Notice the rules condition: isNotCompleted(this):

- *isNotCompleted* is an example of a defined function that may be used as (or as part of) conditional expressions in rule nodes.
- *this* is a special variable created by the Worklet Service that refers to the workitem that the rule is defined for and contains, amongst other things, all of the workitem's data attributes and values.

Tip: The Worklet Service provides developers with an easily extendible class where functions can be defined and then used in conditions. See Appendix 8.7 for more information about defining functions.

In this case, the condition tests if the workitem *Receive_Payment* has not yet completed (i.e. if it has a status of *Fired*, *Enabled*, *Executing* or *Suspended*). If it hasn't completed (thus payment for the order has not yet been received) then the conclusion will be executed as an exception handling process, including the launching of the worklet *SendReminder*.

The *SendReminder* worklet consists of two tasks: *Send Request*, and timer-enabled *Receive Reply* – again, for the purposes of the example, this task waits for 5 seconds before timing out. When the task times out, the Exception Service is notified. There is a single timeout rule for the *Receive Reply* task - its condition is again *isNotCompleted(this)* but this time, the rules conclusion can be seen in Figure 8.53.

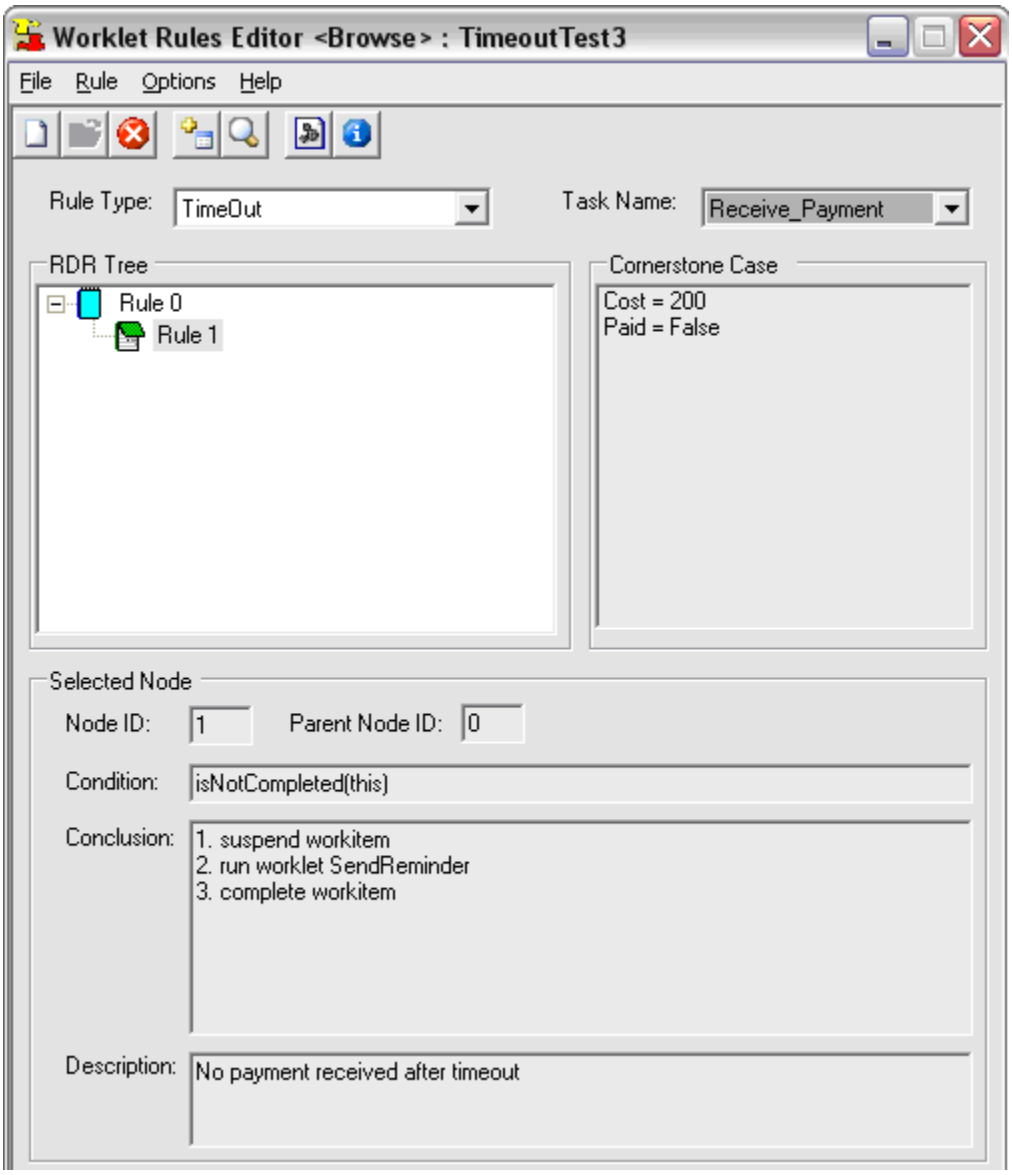


Figure 8.52: Rules Editor Showing Single Timeout Rule for Receive_Payment Task

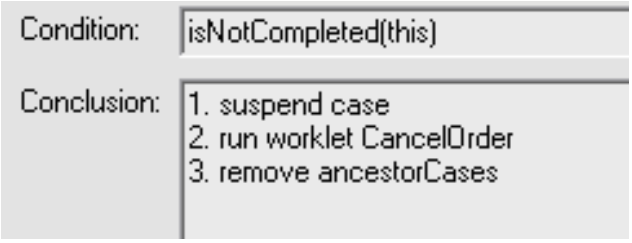


Figure 8.53: Rule detail for Receive Reply

File Cancellation is the first task of the *Cancel Order* worklet. What we now have is a hierarchy of worklets: case (*TimeoutTest3*) is suspended pending completion of worklet case (*Send Reminder*) which itself is suspended pending completion of worklet case (*Cancel Order*). Worklets can invoke child worklets to any depth. Notice the third part of the handling process: "remove ancestorCases". *Ancestor Cases* are all cases

from the current worklet case back up the hierarchy to the original parent case that began the exception chain (as opposed to "allCases" which refers to all currently executing cases of the same specification as the case which generates the exception). So, when the *Cancel Order* worklet completes, the *Send Reminder* case and the original parent *Timeout Test 3* are both cancelled by the Exception Service.

F. Rejecting a Worklet and/or Raising a New External Exception

The processes involved in rejecting a worklet (launched either as a result of the Selection or the Exception Service) and raising a new external exception (that is, an external exception which has not yet been defined - formally an *unexpected exception*) are virtually identical and so are discussed together in this section.

When the Worklet Service launches a worklet, it selects the most appropriate one based on the current case context and the current rule set for the parent case. As discussed previously in this chapter, there may be occasions where the selected worklet does not best handle the current case's context (perhaps because of a new business rule or a more efficient method of achieving the goal of a task being found). In any event, a worker may choose to reject the worklet that was selected.

IMPORTANT: The rejection of a selected worklet is a legitimate and expected occurrence. Each rejection allows for the addition of a new exception rule (or a rule on the true branch of its parent) thus creating a 'learning' system where all events are handled online. When the new rule is added as a result of the rejection, it will return the correct worklet for every subsequent case that has a similar context. Thus, rejecting a worklet actually refines the rule set for a specification.

To reject a selected worklet, go to the *Case Mgt* screen and select in the list of running cases the worklet you wish to reject. Then, click the *Reject Worklet* button (see Figure 8.47). You will be redirected to the *Reject Worklet Selection* screen, another Worklet Service add-in screen (Figure 8.54). This screen displays the Specification and Case ID for the selected worklet. Enter a proposed title (or name) for the new worklet and an explanation of reason for the rejection (in plain text), and then submit the form.

Figure 8.54: Reject Worklet Selection Screen

To raise an unexpected exception at the case-level, follow a similar process at the *Case Mgt* screen, but instead click the *Raise Exception* button. On the *Raise Case-Level Exception* screen (discussed in Walkthrough D), select *New External Exception* from the list and submit the form. You will be redirected to the *Define New Case Level Exception* screen. Enter a proposed title, a description of the scenario (what has happened

to cause the exception) and a (optionally) a proposal or description of how the new worklet will handle the exception (in plain text), and then submit the form. See Figure 8.55 for an example using the *Organise Concert* specification. Raising an item-level exception is identical, except that the *Raise Exception* button is clicked on the *Work Queue* screen, rather than the *Case Mgt* screen.

The information entered on the form is sent to a Worklet Service Administrator, who will action the rejection or new exception by adding a new rule to the rule set and (optionally) having the Rules Editor notify the service to reselect the new worklet using the updated rule set (see Section 8.5.2 on the Rules Editor for more detail). The process requires a user with administrator privileges to action the rejection request, rather than allow all users access to update rule sets.

Note: Rejecting a worklet selection or raising a new unexpected exception will automatically suspend the parent case until such time as the rejection or unexpected exception is actioned by an administrator.

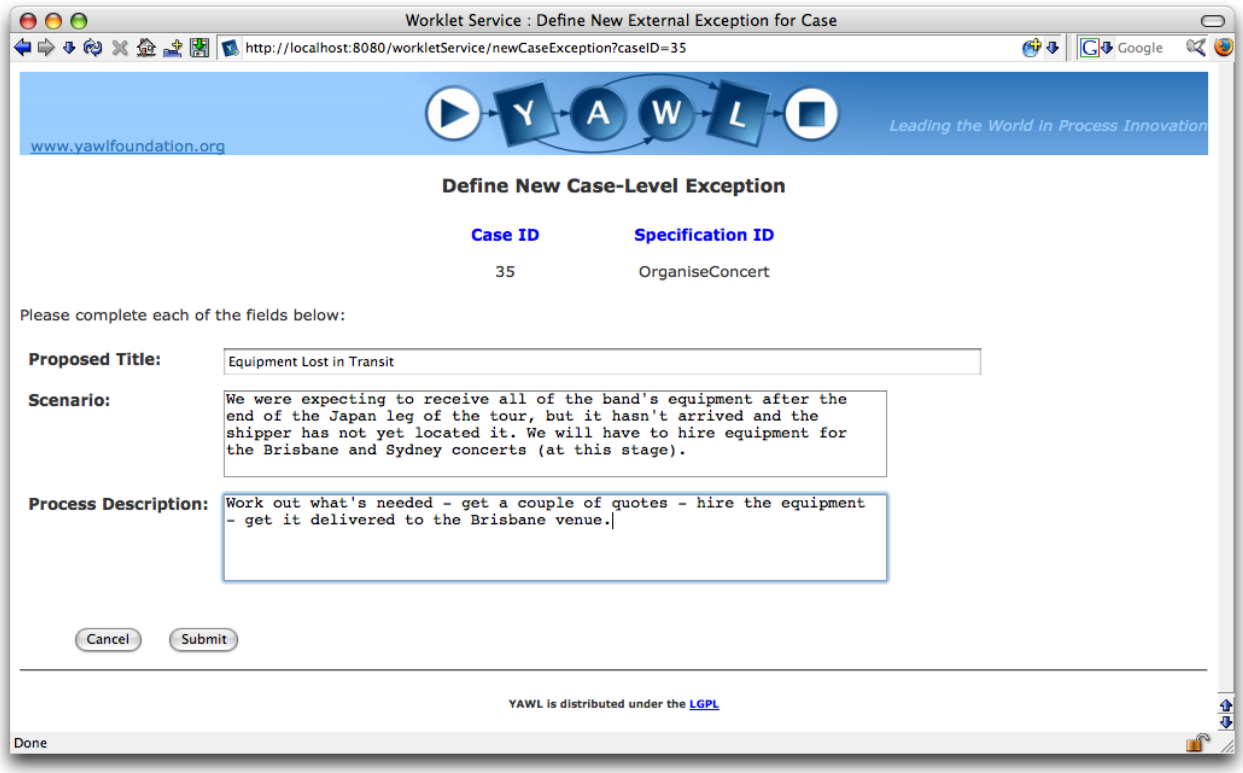

Worklet Service : Define New External Exception for Case
http://localhost:8080/workletService/newCaseException?caseID=35
www.yawlfoundation.org
Leading the World in Process Innovation
Define New Case-Level Exception
Case ID
Specification ID
35
OrganiseConcert
Please complete each of the fields below:
Proposed Title:
Equipment Lost in Transit
Scenario:
We were expecting to receive all of the band's equipment after the end of the Japan leg of the tour, but it hasn't arrived and the shipper has not yet located it. We will have to hire equipment for the Brisbane and Sydney concerts (at this stage).
Process Description:
Work out what's needed - get a couple of quotes - hire the equipment - get it delivered to the Brisbane venue.
Cancel
Submit
YAWL is distributed under the LGPL
Done

Figure 8.55: Example of a New Case-Level Exception Definition

Back at the *Case Mgt* form, if the exception service is enabled, you will notice an extra button in the *Running Cases* panel called *Worklet Admin* (for example Figure 8.47). This button allows administrators to view the current list of outstanding worklet rejections and requests for new exception handlers. It also allows administrators to view the details of each outstanding rejection and exception request and to mark it as completed (removing them from the list) after it has been actioned (Figure 8.56).

8.7 Defining New Functions for Rule Node Conditions

In Section 8.5, we saw how rule conditions could be defined using a combination of arithmetic operators and operands consisting of data attributes and values found in workitems and at the case level of process instances. In *Walkthrough D*, an example of a defined function was given (*isNotCompleted*), using the special variable *this*.

The Worklet Service provides a discrete class that enables developers to extend the availability of such

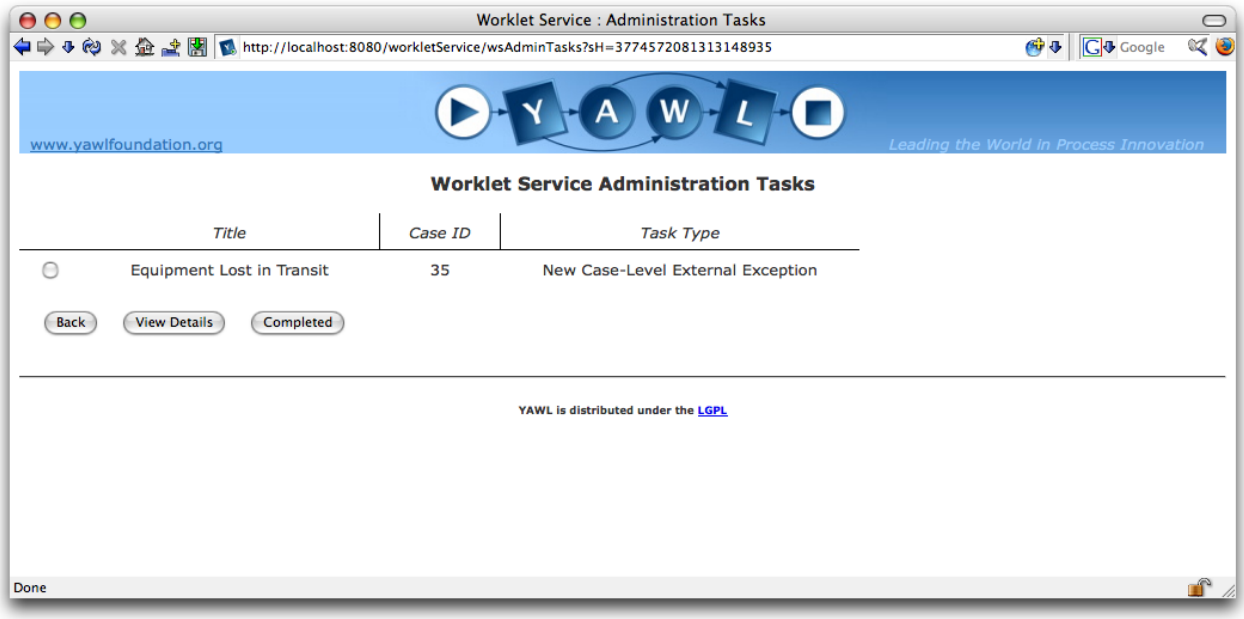


Figure 8.56: Administration Tasks Screen (detail)

defined functions. That is, a developer may define new functions that can then be used as (or as part of composite) conditional expressions in rule nodes. That class is called *RdrConditionFunctions* - the source code for the class can be found in the *au.edu.qut.yawl.worklet.support* package. Currently, this class contains a small number of examples to give developers an indication of the kinds of things you can do with the class and how to create your own functions.

The class code is split into four sections:

- Header;
- Execute Method;
- Function Definitions; and
- Implementation.

To successfully add a function, these rules must be followed:

1. Create the function (i.e. a normal Java method definition) and add it to the 'function definitions' section of the code. Ensure the function:
   - is declared with the access modifier keywords *private static*; and
   - returns a value of *String* type.
2. Add the function's name added to the array of '_functionNames' in the header section of the code.
3. Add a mapping for the function in the 'execute' method, using the examples as a guide.

Once the function is added, it can be used in any rule's conditional expression.

Let's use the *max* function as a simple example walkthrough (to be read in conjunction with the source code for the class). The first thing to do is define the actual function in the function definition section. The entire function is shown in Figure 8.57.

Notice that the function has been declared as *private static* and returns a *String* value. Next, the name of the function, *max*, has to be added as a *String* value to the *_functionNames* array in the header section of the code, see Figure 8.58.

```
public static String max(int x, int y) {
        if (x >= y) return String.valueOf(x) ;
        else return String.valueOf(y) ;
    }
```

Figure 8.57: Max function

```
public static final String[] _functionNames = { "max",
                                                "min",
                                                "isNotCompleted",
                                                "today"} ;
```

Figure 8.58: Adding the name

Finally, we need to map the function name to the *execute* method, which acts as the interface between the class's functions and the Worklet Service. The *execute* method receives as arguments the name of the function to execute, and a *HashMap* containing the functions parameters (all are passed as *String* values). The *execute* method is essentially an *if ... else if* block, the sub-blocks of which call the actual functions defined. The section of the *execute* method for the *max* function is shown in Figure 8.59.

```
else if (name.equalsIgnoreCase("max")) {
    int x = getArgAsInt(args, "x");
    int y = getArgAsInt(args, "y");
    return max(x, y);
}
```

Figure 8.59: Execute method for the max function

The first line checks to see if the name of the function passed to the *execute* method is "max". If it is, the parameters passed with the function (as *String* values in the *HashMap* "args") are converted to integer values and finally the *max* function is called - its return value is passed back from the *execute* method to the calling Worklet Service.

The *getArgsAsInt* method called in the snippet above is defined in the *Implementation* section of the class's code. It is here that you can create private methods that carry out the external work of the any functions defined, as required.

The definition of *isNotCompleted* is slightly different, since the parameter passed is the special variable *this*. The *this* variable is essentially a *WorkItemRecord* that contains descriptors of the workitem the rule is testing, enabling developers to write methods that test the values in the variable and act on those values accordingly. If it is for a case-level rule, this contains the case data for the instance invoking the rule. Both versions of this are passed as a string-ified JDOM Element format. See the YAWL source code for more details of the

WorkItemRecord class, if required.

What the execute methods sub-block for the *isNotCompleted* function looks like is shown in Figure 8.60.

```
if (name.equalsIgnoreCase("isNotCompleted")) {

    String taskInfo = (String) args.get("this");

    return isNotCompleted(taskInfo);

}
```

Figure 8.60: Execute method's sub-block for isNotCompleted function

The block gets *this* variable as a *String* from the "args" *HashMap* and then calls the actual *isNotCompleted* method (see Figure 8.61).

```
public static String isNotCompleted(String itemInfo) {

    Element eItem = JDOMConversionTools.stringToElement(itemInfo);

    String status = eItem.getChildText("status");

    return String.valueOf(! isFinishedStatus(status) );

}
```

Figure 8.61: Calling the actual isNotCompleted method

Notice again that the function has been declared as *private static* and returns a *String* value. The first line of the function converts the *String* passed into the function to a JDOM Element, and then extracts from that Element a value for "status" (being one of the data attributes contained in the *this* variable). It then calls another method, defined in the *Implementation* section, called *isFinishedStatus* (see Figure 8.62).

```
    private static boolean isFinishedStatus(String status) {

        return status.equals(WorkItemRecord.statusComplete) ||

               status.equals(WorkItemRecord.statusForcedComplete) ||

               status.equals(WorkItemRecord.statusFailed) ;

    }
```

Figure 8.62: Definition of method isFinishedStatus

All methods defined in the Implementation section must also be declared as private static methods - however, they can have any return type, so long as the value returned from the *execute* method back to the Worklet Service has been converted to a *String* value.

Of course, you are not restricted to querying the *this* variable as a *WorkItemRecord* - it is passed simply as a JDOM Element that has been converted to a *String* and so can be queried via a number of different methods.

The objective of the *RdrConditionFunctions* class is to allow developers to easily extend the capabilities of the Worklet Service by providing the means to test for other things in the conditional expressions of rule nodes

other than the process instance's data attributes and values. It is envisaged that the class's functions can be extended into areas such as process mining, querying resource logs and external data sets.

8.8 Sample Log (generated by Walkthrough C)

In the following every line started with the date, which has been omitted for readabilty reasons. Similary, "ExceptionService" has been abbreviated to "ES" and "WorkletService" to "WS".

```
12:16:31,875  [INFO ] ES  :-  HANDLE CHECK CASE CONSTRAINT EVENT
12:16:31,984  [INFO ] ES  :-  Checking constraints for start of case 20
                              (of specification: OrganiseConcert)
12:16:32,093  [INFO ] ES  :-  No pre-case constraints defined for spec: OrganiseConcert
12:16:32,109  [INFO ] ES  :-  HANDLE CHECK WORKITEM CONSTRAINT EVENT
12:16:32,156  [INFO ] ES  :-  Checking pre-constraints for workitem: 20:BookStadium_5
12:16:32,281  [INFO ] ES  :-  No pre-task constraints defined for task: BookStadium
12:28:17,968  [INFO ] ES  :-  HANDLE CHECK WORKITEM CONSTRAINT EVENT
12:28:18,000  [INFO ] ES  :-  Checking pre-constraints for workitem: 20:SellTickets_3
12:28:18,015  [INFO ] ES  :-  No pre-task constraints defined for task: SellTickets
12:28:18,078  [INFO ] ES  :-  HANDLE CHECK WORKITEM CONSTRAINT EVENT
12:28:18,093  [INFO ] ES  :-  Checking post-constraints for workitem: 20.1:BookStadium_5
12:28:18,093  [INFO ] ES  :-  No post-task constraints defined for task: BookStadium
12:56:08,000  [INFO ] ES  :-  HANDLE CHECK WORKITEM CONSTRAINT EVENT
12:56:08,015  [INFO ] ES  :-  Checking pre-constraints for workitem: 20:DoShow_4
12:56:08,140  [INFO ] ES  :-  Workitem 20:DoShow_4 failed pre-task constraints
12:56:08,140  [DEBUG] ES  :-  Invoking exception handling process for item: 20:DoShow_4
12:56:08,156  [DEBUG] ES  :-  Exception process step 1. Action = suspend, Target = workitem
12:56:08,171  [DEBUG] ES  :-  Successful work item suspend: 20:DoShow_4
12:56:08,203  [DEBUG] ES  :-  Exception process step 2. Action = compensate,
                              Target = ChangeToMidVenue
12:56:08,343  [DEBUG] WS  :-  Worklet specification 'ChangeToMidVenue'
                              is already loaded in Engine
12:56:08,546  [DEBUG] WS  :-  Launched case for worklet ChangeToMidVenue with ID: 21
12:56:08,578  [INFO ] ES  :-  HANDLE CHECK WORKITEM CONSTRAINT EVENT
12:56:08,593  [INFO ] ES  :-  Checking post-constraints for workitem: 20.2:SellTickets_3
12:56:08,593  [INFO ] ES  :-  No post-task constraints defined for task: SellTickets
12:56:08,593  [INFO ] ES  :-  HANDLE CHECK CASE CONSTRAINT EVENT
12:56:08,593  [INFO ] ES  :-  Checking constraints for start of case 21
                              (of specification: ChangeToMidVenue)
12:56:08,609  [INFO ] ES  :-  No pre-case constraints defined for spec: ChangeToMidVenue
12:56:08,609  [INFO ] ES  :-  HANDLE CHECK WORKITEM CONSTRAINT EVENT
12:56:08,640  [INFO ] ES  :-  Checking pre-constraints for workitem: 21:CancelStadium_3
12:56:08,656  [INFO ] ES  :-  No pre-task constraints defined fortask: CancelStadium
13:02:48,171  [INFO ] ES  :-  HANDLE CHECK WORKITEM CONSTRAINT EVENT
13:02:48,187  [INFO ] ES  :-  Checking pre-constraints for workitem: 21:Book_Ent_Centre_5
13:02:48,234  [INFO ] ES  :-  No pre-task constraints defined for task: Book_Ent_Centre
13:02:48,250  [INFO ] ES  :-  HANDLE CHECK WORKITEM CONSTRAINT EVENT
13:02:48,265  [INFO ] ES  :-  Checking post-constraints for workitem: 21.1:CancelStadium_3
13:02:48,265  [INFO ] ES  :-  No post-task constraints defined for task: CancelStadium
13:10:10,468  [INFO ] ES  :-  HANDLE CHECK WORKITEM CONSTRAINT EVENT
13:10:10,484  [INFO ] ES  :-  Checking pre-constraints for workitem: 21:Tell_Punters_4
13:10:10,500  [INFO ] ES  :-  No pre-task constraints defined for task: Tell_Punters
13:10:10,500  [INFO ] ES  :-  HANDLE CHECK WORKITEM CONSTRAINT EVENT
13:10:10,515  [INFO ] ES  :-  Checking post-constraints for workitem:
                              21.2:Book_Ent_Centre_5
13:10:10,515  [INFO ] ES  :-  No post-task constraints defined for task: Book_Ent_Centre
```

```
13:13:59,281  [INFO ] ES  :-  HANDLE CHECK CASE CONSTRAINT EVENT
13:13:59,281  [DEBUG] ES  :-  Checking constraints for end of case 21
13:13:59,281  [INFO ] ES  :-  No post-case constraints defined for spec: ChangeToMidVenue
13:13:59,296  [DEBUG] ES  :-  Worklet ran as exception handler for case: 20
13:13:59,437  [DEBUG] ES  :-  Exception process step 3.
                              Action = continue, Target = workitem
13:13:59,468  [DEBUG] ES  :-  Successful work item unsuspend: 20:DoShow_4
13:13:59,515  [INFO ] ES  :-  HANDLE CHECK WORKITEM CONSTRAINT EVENT
13:13:59,531  [INFO ] ES  :-  Checking post-constraints fo workitem: 21.3:Tell_Punters_4
13:13:59,531  [INFO ] ES  :-  No post-task constraints defined fortask: Tell_Punters
13:13:59,546  [INFO ] ES  :-  Exception monitoring complete for case 21
13:13:59,750  [INFO ] ES  :-  HANDLE CHECK CASE CONSTRAINT EVENT
13:13:59,875  [DEBUG] ES  :-  Checking constraints for end of case 20
13:13:59,953  [INFO ] ES  :-  No post-case constraints defined for spec: OrganiseConcert
13:14:00,046  [INFO ] ES  :-  HANDLE CHECK WORKITEM CONSTRAINT EVENT
13:14:00,046  [INFO ] ES  :-  Checking post-constraints for workitem: 20.3:DoShow_4
13:14:00,156  [INFO ] ES  :-  No post-task constraints defined for task: DoShow
13:14:00,171  [INFO ] ES  :-  Exception monitoring complete for case 20
```

Chapter 9

Other Services

Because of the open design of the YAWL interfaces, it is possible to design a YAWL Custom Service to perform the work of a task instance using a wide variety of techniques to meet particular needs. Previous chapters have described the Resource and Worklet Services, which, while quite complex, are examples of the sorts of things that can be achieved using Custom Services. This chapter briefly describes a few other custom services, their varied purposes and their use. Please consult the YAWL Technical Manual for detailed information on the development of YAWL Custom Services.

9.1 Web Service Invoker Service

The Web Service Invoker Service (WSInvoker) provides a mediation layer between the Engine and external SOAP web services. In this way, a task can be associated to an operation of a SOAP web service at design-time, and at runtime task instances are routed to the specified SOAP web service through the WSInvoker. Without this layer, a Custom Service would have to be developed between each and every SOAP web service and the Engine on an individual web service basis.

A task is associated with WSInvoker by opening the Task's Decomposition dialog in the Editor and choosing the WSInvoker from the list of available services (Figure 9.1). The service will supply to the task three variable definitions which will require supplied values when the service is invoked at runtime:

- **YawlWSInvokerWSDLLocation**: specifies the URI of the WSDL file describing the web service to invoked;
- **YawlWSInvokerPortName**: specifies the port binding that the web service listens on for interaction with external clients and protocols; and
- **YawlWSInvokerOperationName**: specifies the name of the operation to be executed within the web service.

In addition, any data values that are required for the web service's operation must also be specified within the task decomposition; these are passed to the specified web service when it is invoked. The WSInvoker Service then waits until the external service responds, then returns a mapping of the resultant data to the task instance's output data parameters. Note that when a task is registered with the Invoker Service at design time, the Editor automatically populates the task's input parameters with the required data attributes above.

At present, the WS-Invoker Service supports only SOAP over HTTP and request-response and one-way interactions (out-in and out-only message exchange patterns).

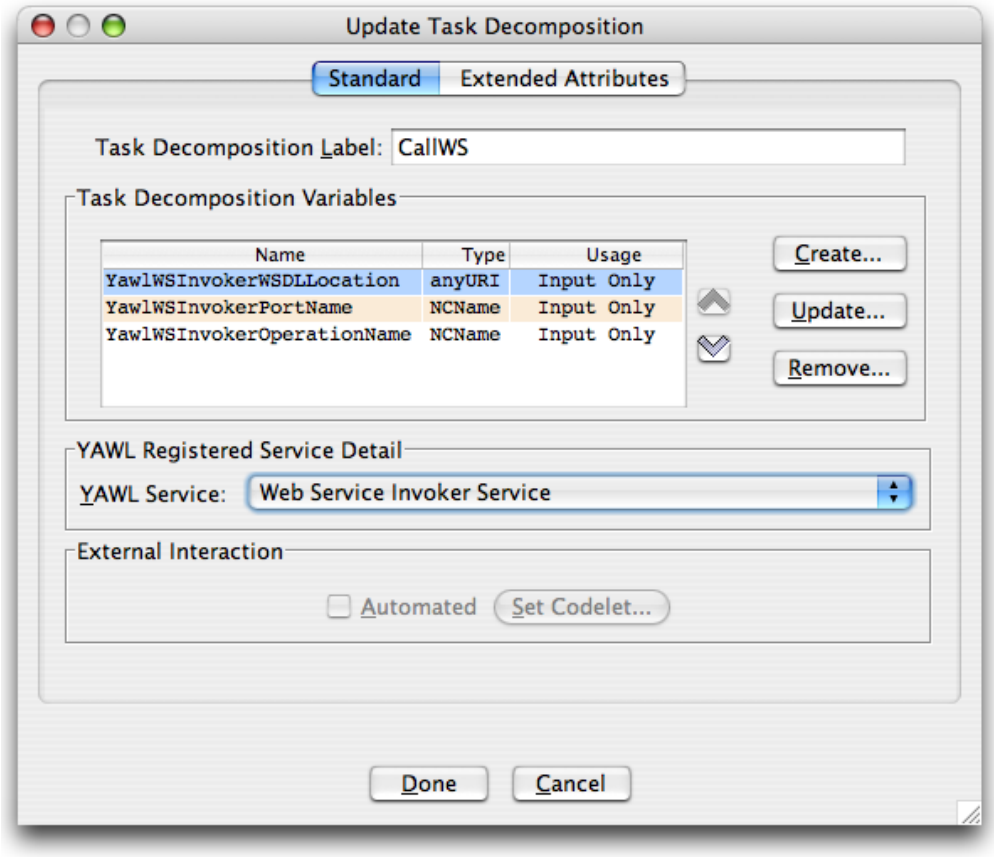


Figure 9.1: Task Decomposition Dialog for WSInvoker-associated task

9.2 SMS Service

The SMS service can use any third-party SMS Gateway web service to send and receive SMS messages and pass the data into and out of the YAWL Engine. In this way, participants can view, update and complete task instances via mobile phones and other SMS capable devices. The service is pre-configured in its web.xml file with four values – a userid and password for an SMS account known to the specified SMS Gateway web service, and its send and receive URI's. These values will be particular to each SMS Gateway service provider.

Like the WSInvoker Service, when a task is associated with SMS Service by opening the Task's Decomposition dialog in the Editor and choosing the SMS Service from the list of available services (Figure 9.2), the service will supply three variables required for the successful operation of the service:

- **SMSMessage**: The message text to send to the mobile device;
- **SMSPhoneNumber**: The phone number of the mobile device to call; and
- **SMSReplyMessage**: The message text that is returned from the mobile device.

When invoked at runtime, the SMS Service will logon to the SMS Gateway provider using the userid and password supplied via the web.xml file, then if successful will pass the SMSMessage and SMSPhoneNumber values to to the service's 'Send' URI. The SMS Gateway provider will send the text message to the mobile device identified by the phone number. It will then wait for a reply message from the device, which it will pass back through the SMSReplyMessage variable which can then be mapped back to a corresponding net-level variable in the process for display in a subsequent task.

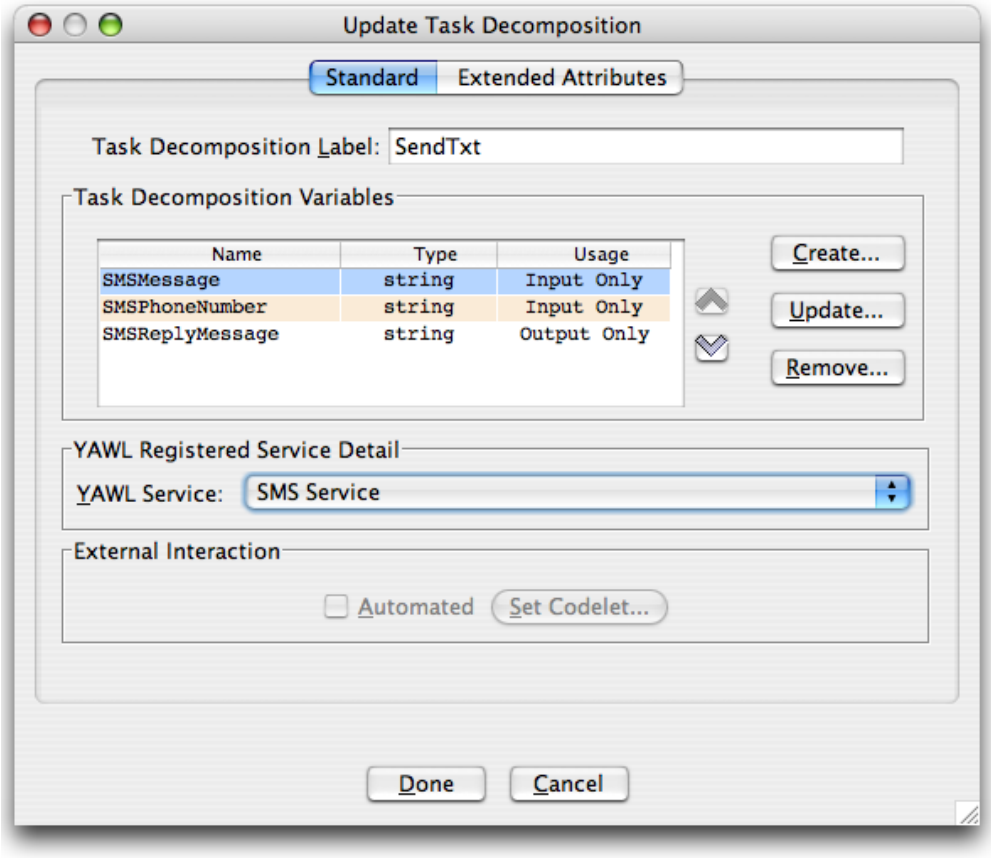


Figure 9.2: Task Decomposition Dialog for SMS Service-associated task

9.3 Mail Service

The Mail Service was introduced in YAWL 2.2 as a replacement or alternative to the Mail Sender Service. The new Mail Service allows a task to be designated as an *email* task, which can then be easily configured to send an email to a recipient, using SMTP.

The Mail Service has several parameters that are required to be configured to successfully send an email. Most of the parameters can have default values set for them in the service's *web.xml* file, so that at runtime a user only has to supply values for those remaining parameters that haven't had default values set. The full list of parameters are:

- **host**: The URL of the SMTP mail host. In the service's web.xml, a sample host value of `smtp.gmail.com` has been supplied, but should of course be changed to whatever host you use to send mail.
- **port**: The port number that the host listens on for SMTP traffic. Again, a default value is supplied (for the gmail host) but should be changed to the correct port for your host.
- **mailUserName**: The username of a registered account on the host that is capable of sending mail.
- **mailUserPassword**: The corresponding password for the supplied username.
- **senderName**: the actual name to associate with the email sender.
- **sendAddress**: the email address of the sender, that is the address of the email account corresponding to the *mailUserName* account on the given host.

Note that any, all or none of the parameters listed above may be given default values in the service's web.xml. Each one without a default value will be requested from the user at runtime. Note also that you may include parameters that already have default values in the task decomposition so that at runtime values are requested from the user – when the user supplies a value for which a default value already exists, the runtime user supplied value will take precedence.

Figure 9.3 shows the Editor's task definition dialog for a task that has been associated with the Mail Service. Notice that the list of task variables has been populated by the service. For each of the default parameters supplied via web.xml, you may simply remove the matching task variable from the list for all those parameters you don't want the user to override at runtime (e.g. Figure 9.4 has removed the variables for all the default values). The output-only variable *result* is used by the service to return the outcome of the send (i.e. either a success or error message).

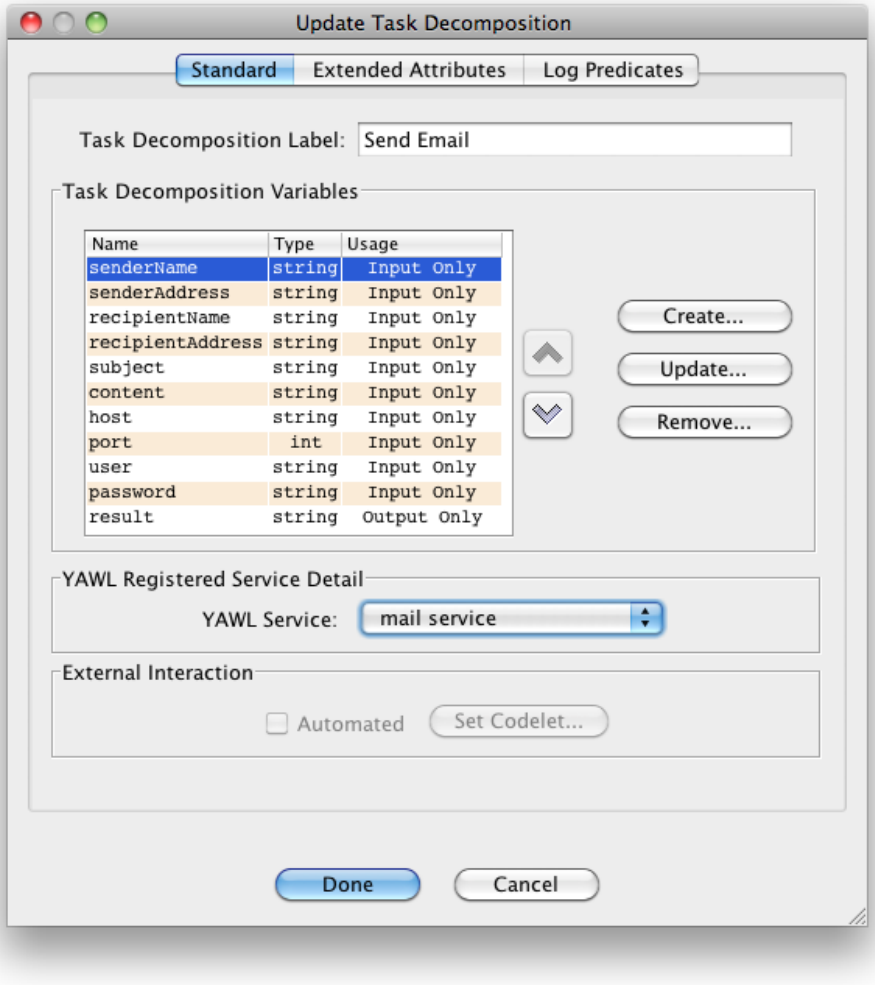


Figure 9.3: Task Decomposition Dialog for a Mail Service associated task

Generally, a *Send Email* task associated with the Mail Service will be preceded by another task the will collect the required non-default values from a user at runtime. An example of a dynamic form for such a task is shown in Figure 9.5 – of course, a custom form may also be used if desired. The *content* field in figure 9.5 uses a *textarea* extended attribute to provide ample space to input the required email content.

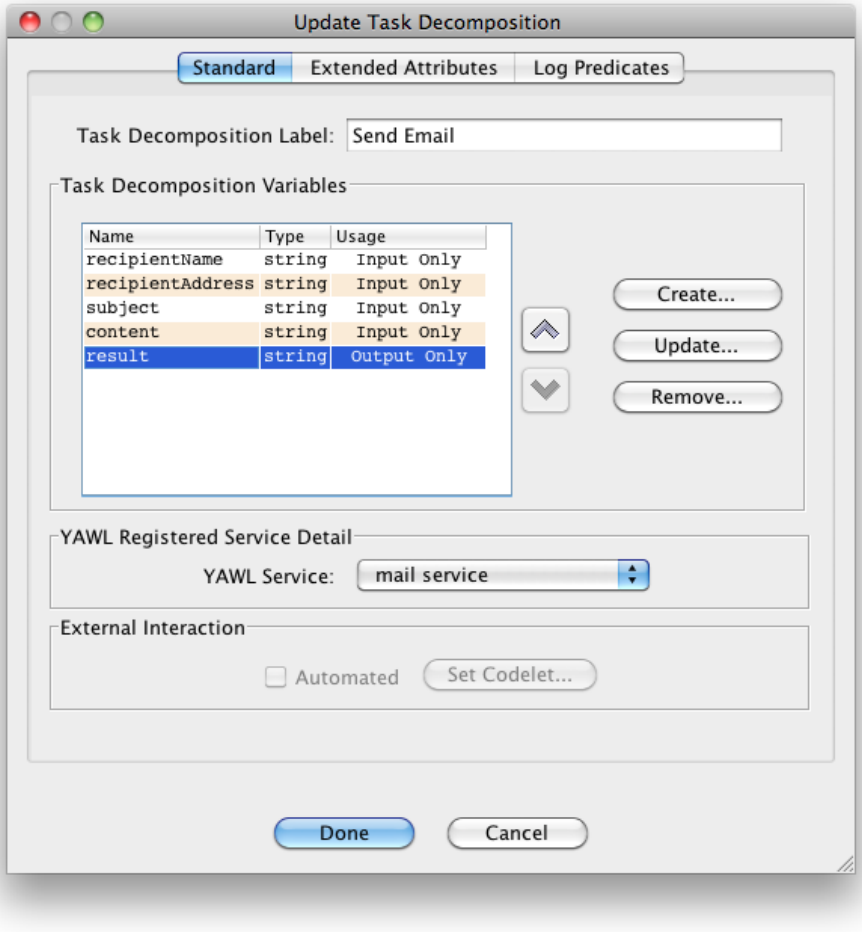


Figure 9.4: Task Decomposition Dialog for a Mail Service, variables with default values removed

9.4 Twitter Service

The Twitter Service is a simple service that provides for the posting of status updates (i.e. 'tweets') to Twitter.

When a task is associated with Twitter Service in the Editor's Task Decomposition dialog, the service will supply two required variables:

- **status**: (Input-Only) The message text to send to Twitter;
- **result**: (Output Only) A response message received from Twitter that indicates the success or failure of the status update.

When invoked at runtime, the Twitter Service will connect to Twitter and, through its API using the configured userid and password, post the status update (if connection was successful) and put Twitter's response text in the result variable.

Note: the Twitter API requires a set of four authorised OAUTH tokens to log on, which are stored in the service's *twitter4j.properties* file (twitter4j[1] is the name of the third party library the service uses to communicate with Twitter). Two OAUTH tokens, *oauth.consumerKey* and *oauth.consumerSecret* identify the YAWL TwitterService and should not be changed. The other two tokens, *oauth.accessToken* and *oauth.accessTokenSecret* define the username and password of the Twitter account being used to logon to Twitter – those in the proper-

[1] twitter4j.org

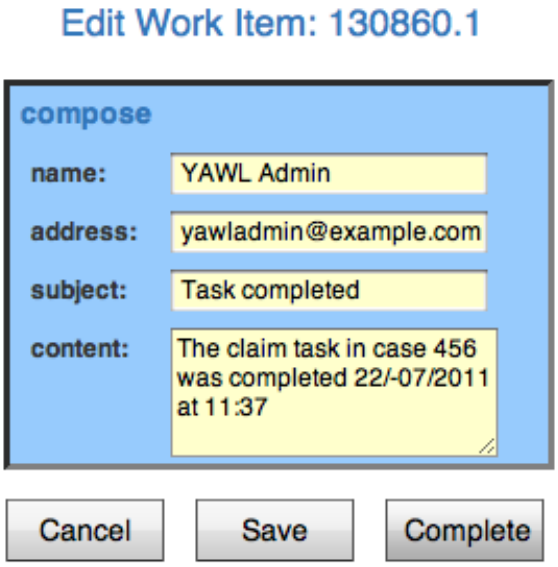


Figure 9.5: A dynamic form for a typical 'compose email ' task

ties file are for the default twitter user *YAWLProc*. To use the service with a different Twitter user account, replace the *oauth.accessToken* and *oauth.accessTokenSecret* values with those generated from the other account. A simple guide to generating tokens for another twitter account can be found here: `http://goo.gl/cyHaR`

9.5 Digital Signature Service

The purpose of the digital signature is not to hide the data on the form (captured as an XML ComplexType) but to ensure the authenticity of the information. This custom service is composed of two functions, the first one is to sign the XML form and the second one is to check the validity of the signature created by the first one.

9.5.1 Signing a Document

1. The Document is hashed with a hashing algorithm to encrypt it and to reduce its volume.
2. The Private Key is extracted from inside the key store certificate 'p12'. To do this, we need the publisher's password which is only known by him/her.
3. Combine the private key, the Document fingerprint and the X.509 certificate to create the digital signature using 'PKCS#7' encryption.
4. The fingerprint and the private key are used to calculate the signature itself and the X.509 certificate gives the publisher details.

A digest-SHA1 of the document is included in the signature. Since the Document has a unique fingerprint, the digital signature only applies to this document.

The p12 certificate is protected by a password and is only used to sign the document. The public certificate X.509 contains the information about the signer and the public key that can be used to check the validity of the signature. It is public because anybody should be able to access the content of the signature to verify it. But without the private key it cant be reproduced.

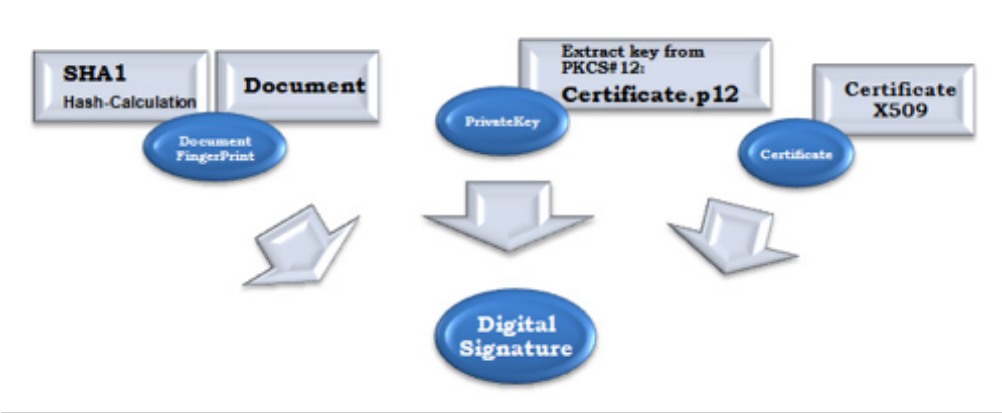


Figure 9.6: An overview of the production of a digital signature

9.5.2 Verification of the Digital Signature

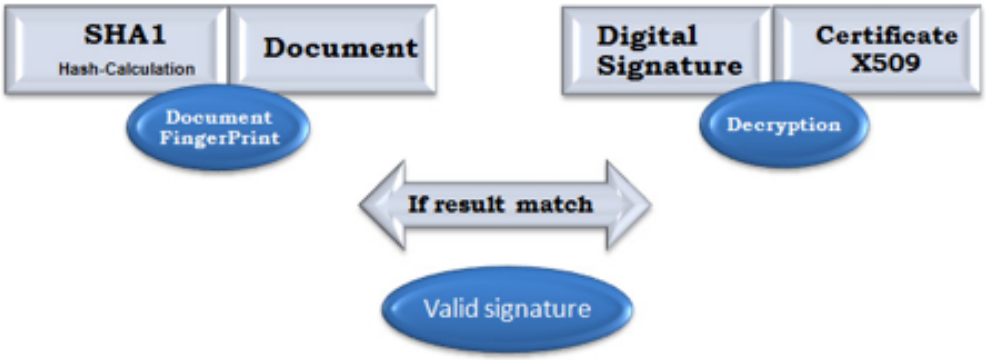


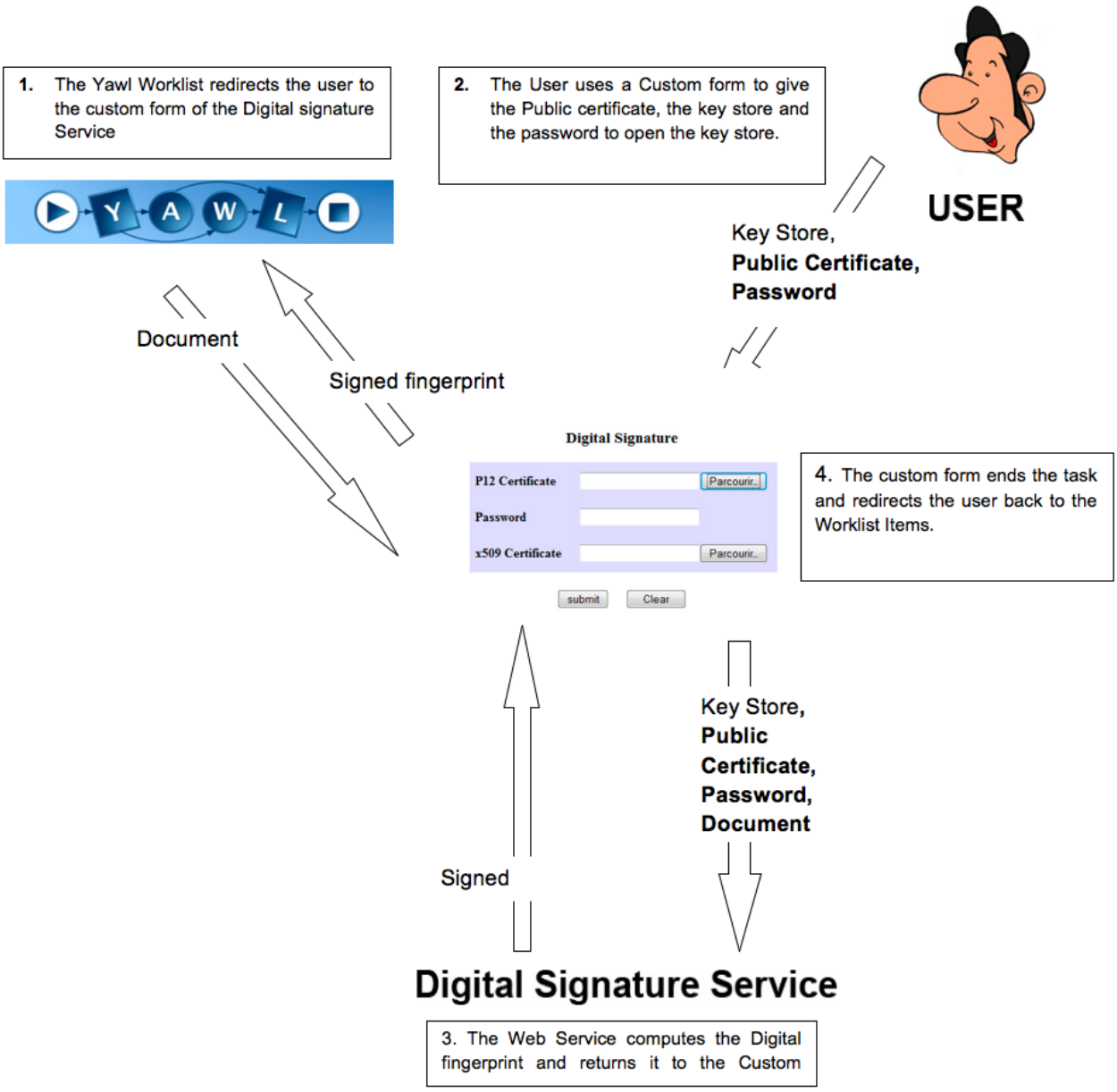
Figure 9.7: An overview of the verification of a digital signature

1. Calculate the document fingerprint with the same algorithm than the signer used.
2. To verify the Digital Signature you need first to extract the certificate X.509. The certificate X.509 contains all the information needed to identify a user. It is not encrypted and can be seen freely. We use the public key contained in this certificate to decrypt the signature using the same algorithm.
3. If the signature matches the digest message of the document then the signature is considered valid.

Anybody can verify the signature since the public key is contained in the X.509 certificate. It is hard to reproduce this signature as the private key is only contained in the certificate PKCS#12 and it needs the owners password to be extracted. Also if the signature is slightly modified the digest function won't match the signature anymore.

9.5.3 Interaction between a YAWL custom form and the service

Before you can use the digital signature function, the user will need to create a digital certificate. These certificates are provided by a CA (certificate authority), for example Thawte Consulting for X.509 certificates. It is advisable to use a certificate provided by a trusted third party like CA but you can also create your own certificates using some open source tools.


1. The Yawl Worklist redirects the user to the custom form of the Digital signature Service
2. The User uses a Custom form to give the Public certificate, the key store and the password to open the key store.
USER
Key Store, Public Certificate, Password
Document
Signed fingerprint
Digital Signature
P12 Certificate
Parcourir...
Password
x509 Certificate
Parcourir...
submit
Clear
4. The custom form ends the task and redirects the user back to the Worklist Items.
Key Store, Public Certificate, Password, Document
Signed
Digital Signature Service
3. The Web Service computes the Digital fingerprint and returns it to the Custom

9.5.4 Creating a New Certificate

New certificates can be easily created using *Key tool IUI*, which can be downloaded from: www.softpedia.com/get/Security/Security-Related/KeyTool-IUI.shtml.

The first step is to create an empty Key Store PKCS12 locked with your password. Save the empty key store in a chosen location (Figure 9.8).

Then use this key Store to generate the key pair and the X.509 certificate by filling in the owner information (Figure 9.9).

When the key pair is created you can review the certificate information produced (Figure 9.10).

When the key pair is ready you can export the certificate via Export → Private Key's first signing certificate file → as simple certificate file (Figure 9.11).

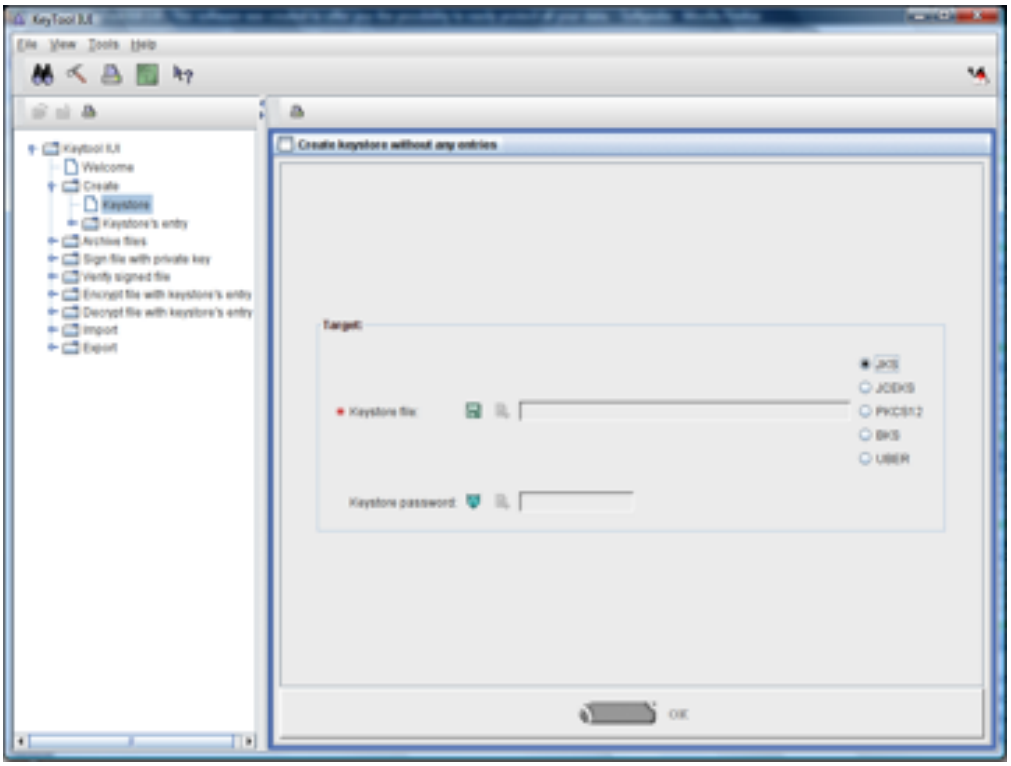


Figure 9.8: Creating an Empty Keystore

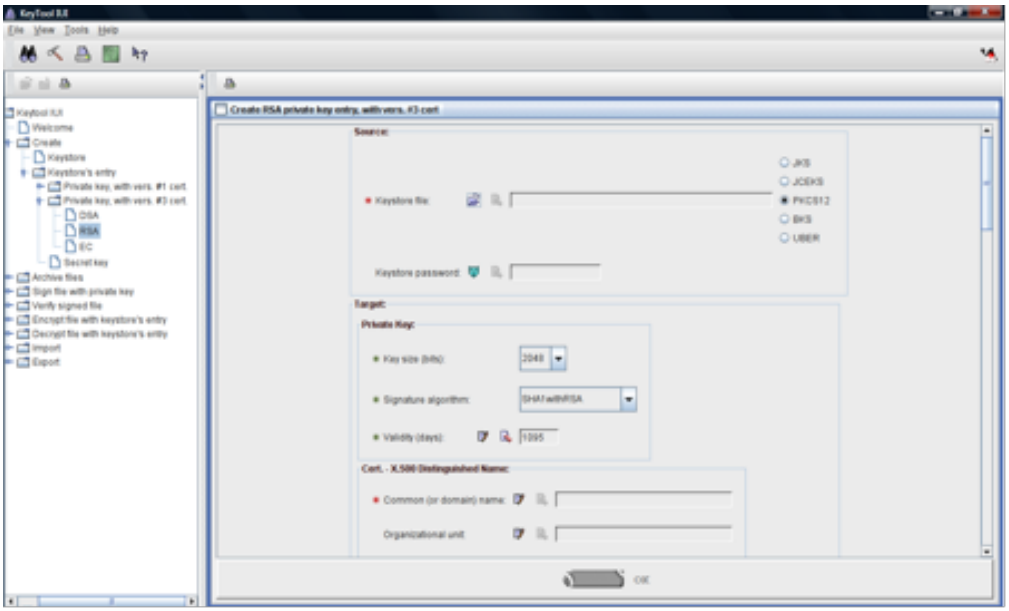


Figure 9.9: Generating the Key Pair

9.5.5 Using the Digital Signature Service

First please make sure that you have copied the DigitalSignature.war in your tomcat/webapps folder. In the simplest case of using the Digital signature service you will need at least three tasks (Figure 9.12).

The first task 'Fulfil Document' is a user task that can contain any complex type of document (i.e. a variable)

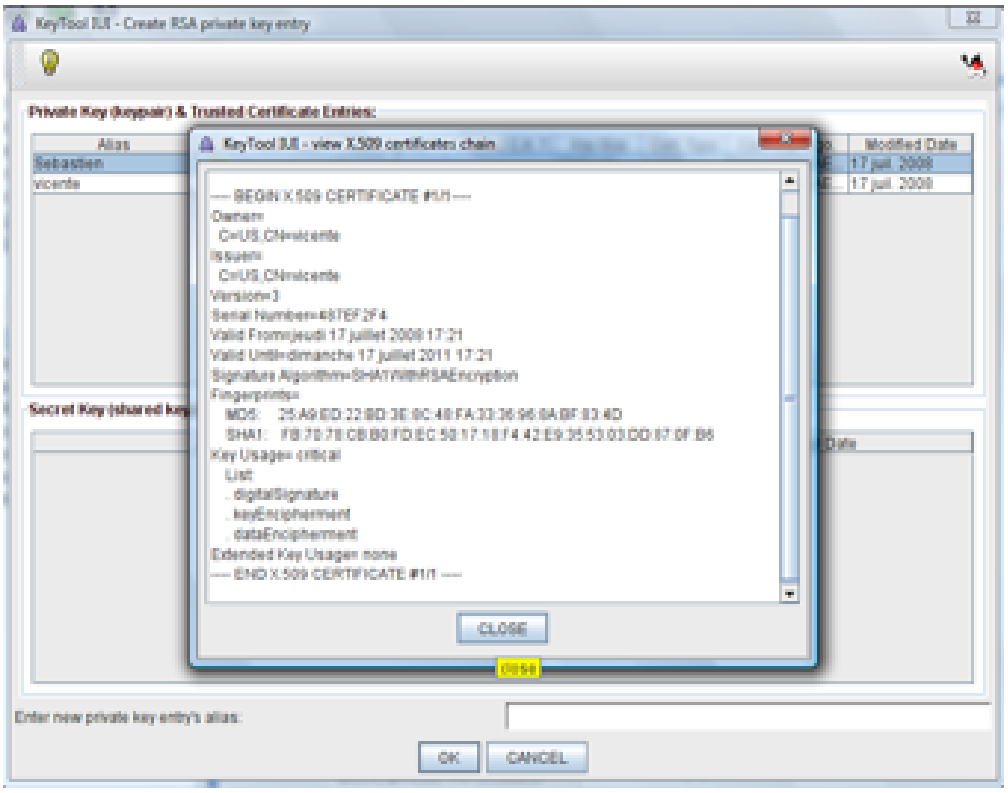


Figure 9.10: The Created Certificate

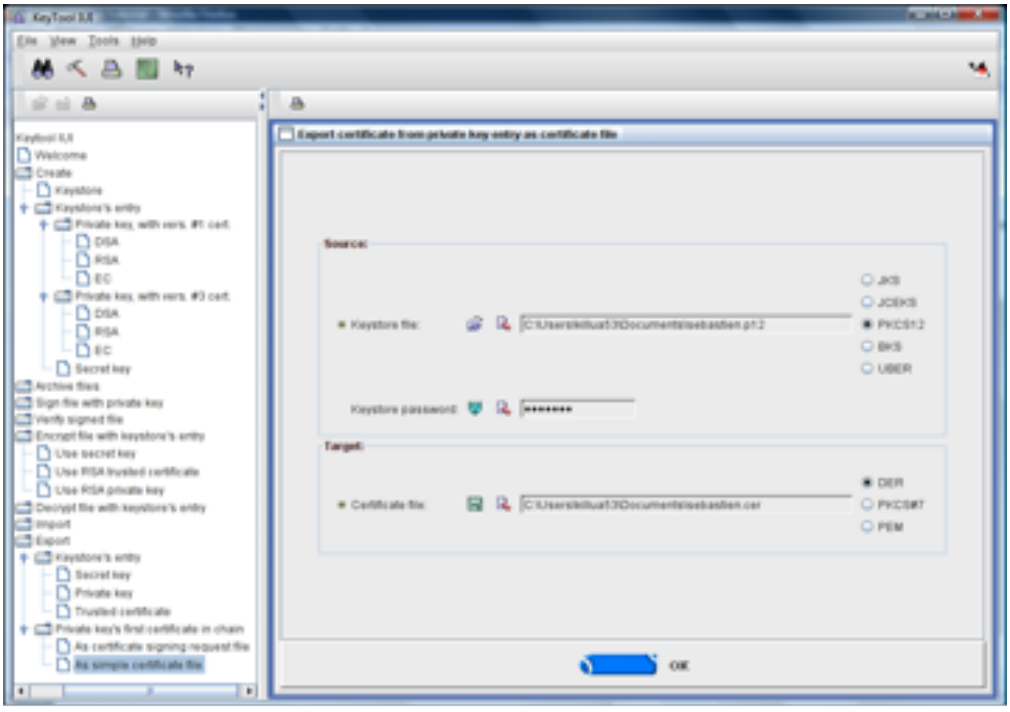


Figure 9.11: Exporting the Certificate

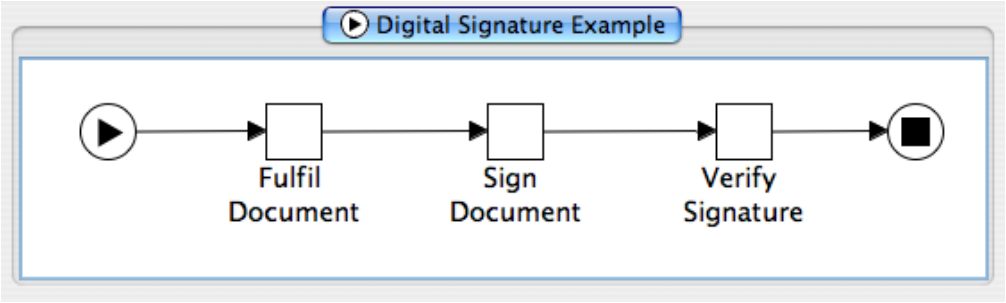


Figure 9.12: Example YAWL Process

you want to be signed. You can define your complex type in the 'Update Data Type Definition' dialog of the Editor, as the example in Figure 9.13:

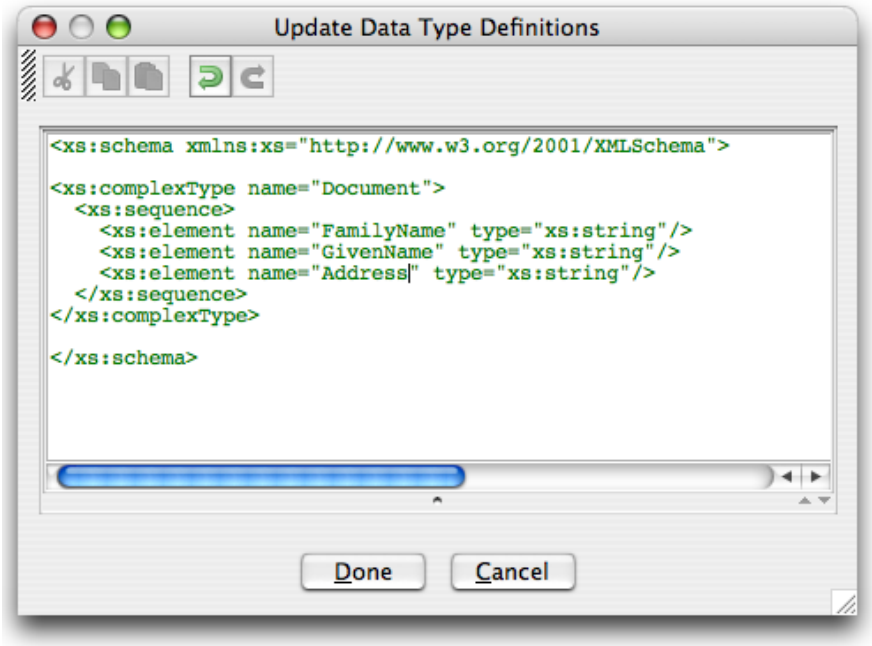


Figure 9.13: Data Definition for 'Document' type

The second task 'Sign Document' redirects the user to a custom form which is located inside the 'DigitalSignature.war' deployment. We use a custom form to directly deal with the user instead of a standard custom service because private data like the key store password needs to be hidden from YAWL as the data is passed from one task to another as a net variable, which is accessible by any other task. You can define the Custom Form URI for the task by right-clicking on the task in the Editor, choosing 'Set Custom Form' from the menu, and then entering the URI of the form in the dialog shown (Figure 9.14).

You also have to define the task data that will be used by the custom form. In this example, their names should be 'Document' and 'Signature'. Note that usage type of the 'Signature' is Input & Output.

You may also have to change the paths in the 'upload.jsp' file: where the default values are 'localhost', they may have to be changed to the actual address where the service runs (if it is not running locally):

```
String Path = "http://localhost:8080/DigitalSignature/files/";
String redirectURL = "http://localhost:8080/resourceService/" +
                     "faces/userWorkQueues.jsp?workitem=" +
                     wir.toXML();
```

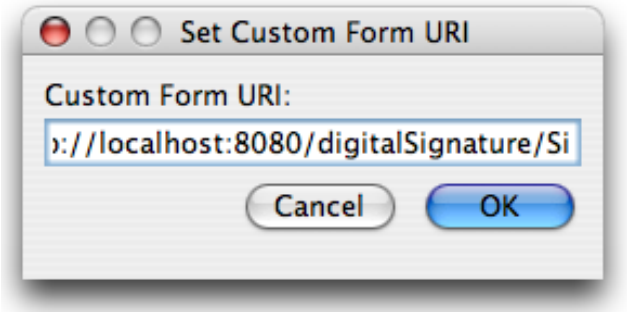


Figure 9.14: Custom Form dialog in YAWL Editor

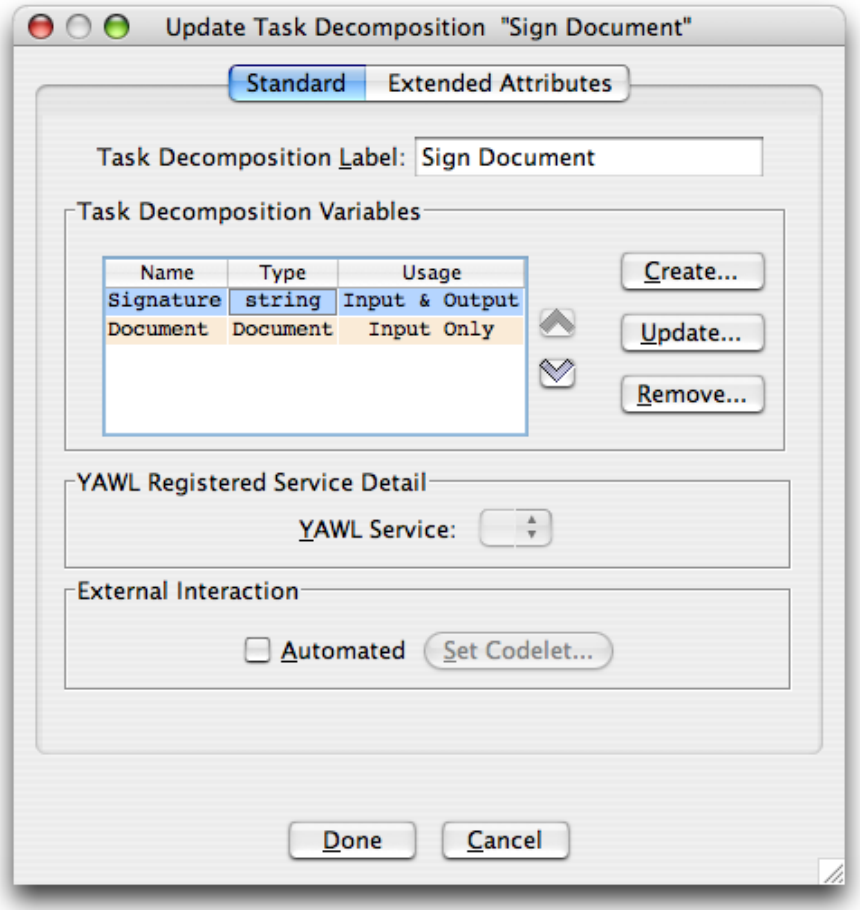


Figure 9.15: Task variables for the 'Sign Document' task

The last task is the custom service part; it has to be specified in the 'YAWL Registered Service Details' panel of the Task Decomposition dialog (Figure 9.16).

The Signature will be checked with the certificate loaded in the jsp page and it will provide the document which has been signed. Note that the 'Document' variable is an "anyType" type, to be able to check back any complex type you may have signed.

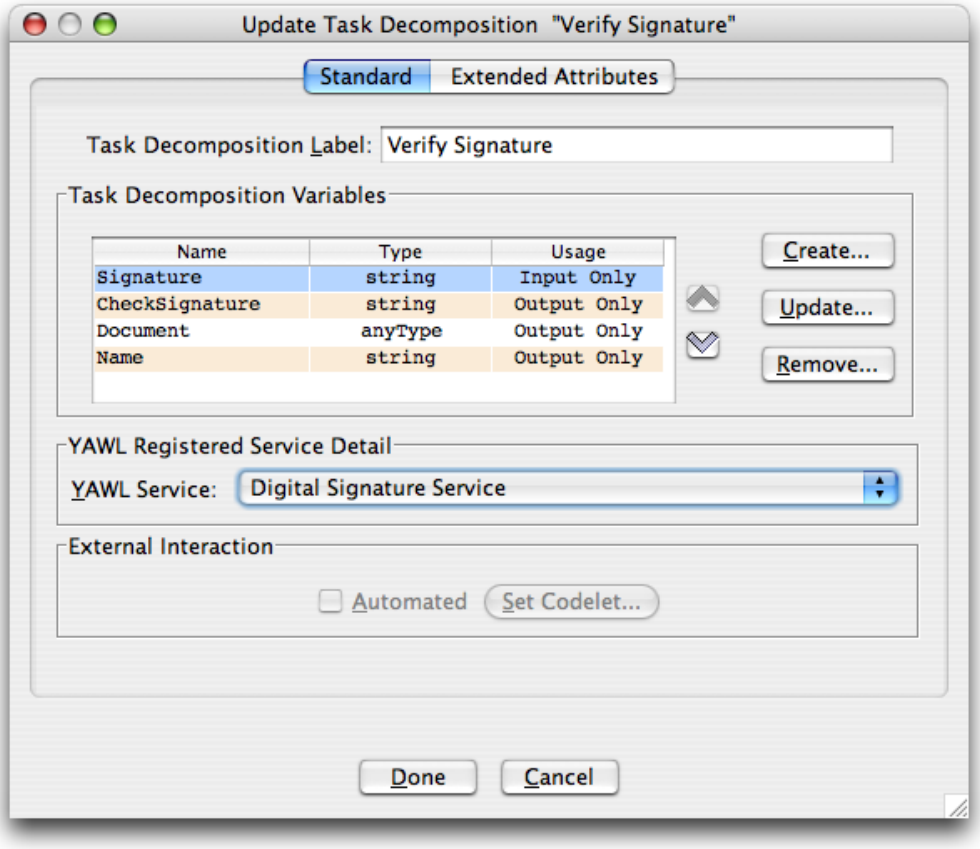


Figure 9.16: Task variables and service details for the 'Verify Signature' task

9.6 Email Sender Service

NOTE: This service has been superseded by the Mail Service (cf. Section 9.3).

The Email Sender Service allows users to send simple emails from within the workflow process instance.

9.6.1 How to use the Service

First please make sure that you have the 'mailSender.war' file deployed in your tomcat/webapps folder. The Mail Sender Service uses a YAWL custom form for sending a simple mail notification. You just need one task and set the custom form of that task to call the Mail Sender jsp file. First create a net that will use the Mail Sender Service (Figure 9.17).

Note that you don't need to create a variable to use the Mail Sender but the task that uses it will need at least one variable defined so that the YAWL worklist's view/edit button will not be available and you will not be able to access the Custom form menu.

Second define the Custom form for the task, by right-clicking on the task and selection 'Set Custom Form' from the menu. The address of the custom form is: `http://localhost:8080/mailSender/WebMail.jsp` (remember to replace 'localhost' with the specific hostname when the service is not installed locally).

When invoked at runtime, the custom form will look like the example in Figure 9.18.

You can see that the form in Figure 9.18 contains two parts. The first is to set the SMTP parameters to send email:

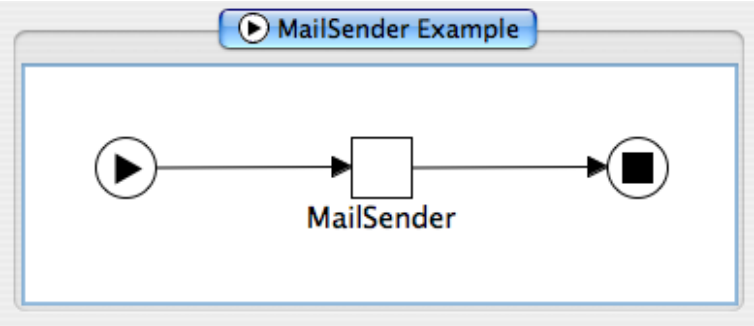


Figure 9.17: Example Mail Sender Process

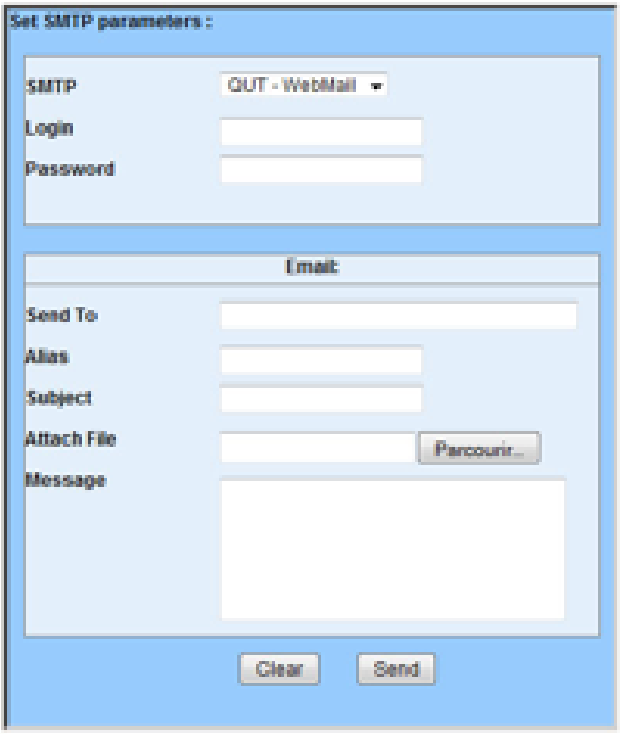


Figure 9.18: Example Mail Sender Custom Form

1. You need to chose in the dropdown list which SMTP you would like to use to send emails.
2. You also need to enter login and password to connect to the SMTP server.

To add another SMTP server, you have to edit WebMail.jsp and add an option=value pair to the dropdown list of servers:

```
<select name="SMTP" onChange="messageValue()">
   <option value="smtp.qut.edu.au">QUT - WebMail</option>
   <option value="smtp.gmail.com">Gmail</option>
   <option value="smtp.mail.yahoo.com">Yahoo</option>
   <option value="New.SMTP">Name in the dropdown list</option>
</select>
```

The second part of the form is for entering the details of the email. In the field 'Send To' enter the email

address to send the mail to. The 'Alias' will be the name appearing on the receiver's mailbox. Then you can add the subject of the mail and the content. You can also attach a file, if desired.

The service will then attempt to send the email using the smtp server details provided in the form.

Chapter 10

Seeking Help

Manuals, like the software they describe, can never be considered to be complete. It is quite possible that you run into an issue for which the documentation is lacking, or find a problem with the YAWL environment that constitutes a bug. Alternately, you may come up with a new idea on how to enhance the system. Here we briefly address the questions of how and where to seek help.

For queries about the YAWL software, we recommend that people use the help and discussion forums at the YAWL Foundation (http://www.yawlfoundation.org/forum) or alternately, the YAWL sourceforge site (http://sourceforge.net/projects/yawl). In posting a question, request or comment, please help us as much as possible in answering you by explicitly stating which versions of various software components you are using, providing the specification that is causing a problem if applicable, listing messages produced in the console window and/or log files, providing a backup of the database, and so on. Allow up to a few days for someone to respond to your request.

The YAWL Issues Tracker (code.google.com/p/yawl) can be used for reporting bugs or proposing enhancements. As attachments can be easily provided, this is the preferred method for reporting bugs or requesting enhancements. Again, please provide as much relevant information as possible. Also, before reporting an issue, carefully search the list to ensure that the issue has not already been reported.

Any feedback regarding this manual is most welcome and may be sent to yawlmanual@gmail.com.

We encourage forum posts, bug reports and enhancement requests. Providing these centrally means that others can learn from the answers provided and, hopefully, people are inspired to respond to other people's requests. In this way we can manage progress on YAWL more efficiently.

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